

**City of Beaumont:**  
**Water System Assessment in Response to Discolored**  
**Water Events**  
**FINAL**

**Corona Environmental Consulting**  
**5/19/2022**

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## Executive Summary

The City of Beaumont (City), TX is located about 85 miles east of Houston. The City's water system serves approximately 130,260 residential and commercial customers through 49,263 service connections in Jefferson County, Texas<sup>1</sup>. The Pine Surface Water Treatment Plant (SWTP) is rated at 40 million gallons per day (MGD). The Loeb Groundwater Treatment Plant (GWTP) is a 17 MGD facility. In the past, the City has experienced deep freezes and hurricane-related water quality issues. More chronically, the City has been challenged with discolored water in its distribution system, presumed by the City to be due to the presence of iron and manganese. In recent months, this problem has intensified during a period of fire hydrant testing resulting in increased number of customer complaints.

The City engaged Corona Environmental Consulting (Corona) to provide a review and assessment of the existing water system, with a focus on investigating the discolored water complaints. This assessment included a review of historical source, treated and distribution system water quality from both the SWTP and GWTP. This assessment also included a review of operational and performance data of individual treatment processes, and a site visit to gather input from operations staff. The specific objectives of this study are provided below:

- Review raw and treated water quality to identify sources or causes of iron or manganese
- Review operational parameters of each treatment process to determine areas for improvement
- Develop recommendations for short-term and long-term implementation

Corona prepared and submitted a comprehensive data request that included past engineering reports, design plans, distribution system maps, and past 5 years of water quality, process control, and operational data. Corona staff also performed a 2-day site visit that entailed walking through the SWTP from the raw water intake to each process unit until the finished water at the high service pumps, similarly for the GWTP, and the storage tanks in the distribution system. Corona performed field testing at the SWTP and storage tanks.

The high impact recommendations to minimize discolored water are summarized and identified by location in Table 1; these will have the greatest effect on reducing discolored water in the distribution system. All recommendations developed from this project phase are outlined in detail in Table 8 and Table 9 at the end of this report with priority schedules for implementation.

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<sup>1</sup> Based on data from TCEQ Drinking Water Watch database (<https://dww2.tceq.texas.gov/DWW/>) on 3/30/2022

Table 1. High Impact Recommendations to Minimize Discolored Water

Recommendation	Location		
	Pine Street SWTP	Loeb GWTP	Distribution System
Implement chlorine dioxide to oxidize and remove manganese	X		
Consistently monitor manganese	X	X	
Optimize filter cleaning frequency and duration	X		
Routinely inspect and clean all treated water storage tanks; City is halfway through this process			X
Develop and implement a unidirectional flushing plan			X

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## Introduction

The City of Beaumont (City), TX is located about 85 miles east of Houston. The City's water system serves approximately 130,260 residential and commercial customers through 49,263 service connections in Jefferson County, Texas<sup>2</sup>. The Pine Street Surface Water Treatment Plant (SWTP) is rated at 40 million gallons per day (MGD). The Loeb Groundwater Treatment Plant (GWTP) is a 17 MGD facility consisting of three deep wells, four high service pumps, and two 5 MG ground storage tanks. The City has six elevated water storage tanks with 6.8 MG of storage capacity, four groundwater storage tanks with 17.7 MG of storage capacity, for a total of 24.5 MG of finished water storage capacity in their distribution system. In the past, the City has experienced deep freezes and hurricane-related water quality issues. More chronically, the City has been challenged with discolored water in its distribution system, presumed by the City to be due to the presence of iron and manganese. In recent months, this problem has intensified during a period of fire hydrant testing resulting in increased number of customer complaints.

The City engaged Corona Environmental Consulting (Corona) to provide a review and assessment of the existing water system, with a focus on investigating the discolored water complaints. This assessment included a review of historical source, treated and distribution system water quality from both the SWTP and GWTP. This assessment also included a review of operational and performance data of individual treatment processes, and a site visit to gather input from operations staff. The specific objectives of this study are provided below:

- Review raw and treated water quality to identify sources or causes of iron or manganese-related discolored water
- Review operational parameters of each treatment process to determine areas for improvement
- Develop recommendations for short-term and long-term implementation

This report provides background on the SWTP and GWTP, brief process descriptions, summary of water quality, observations from the site visit, treatment plant and distribution system evaluations. Recommendations for short- and long-term implementation and suggested next steps are also included in this report. In addition to water quality and process improvements, recommendations also include additional monitoring and process control, and improving data management and documentation procedures.

## Pine Street SWTP

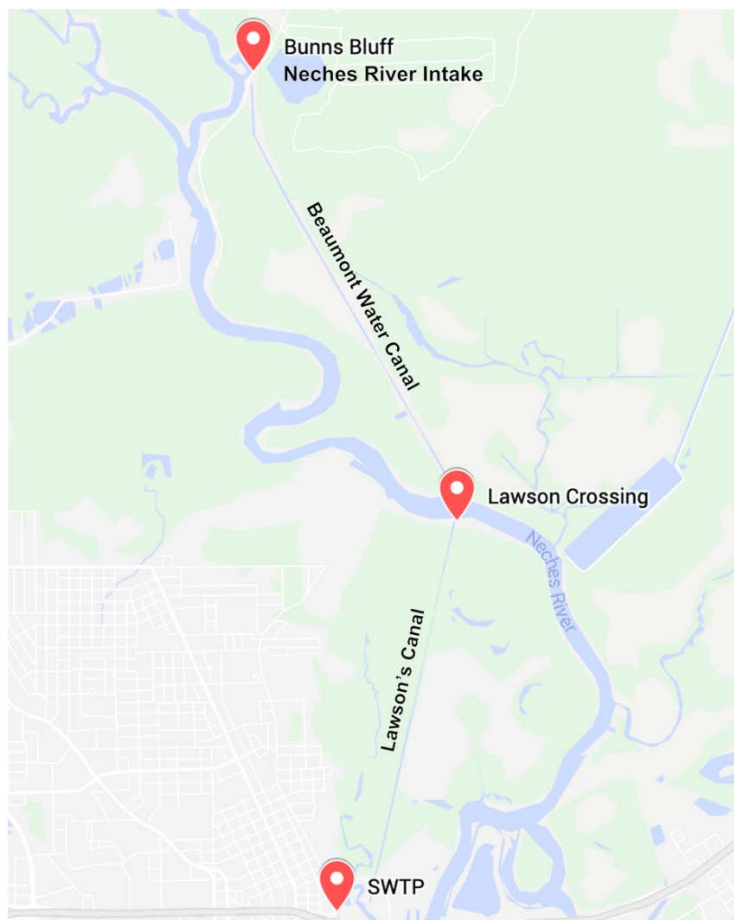
### Process Overview

The SWTP consists of one intake on the Neches River about five miles from the SWTP. The SWTP was originally constructed in the mid-1920s and has recently been upgraded to its current 40 MGD rated capacity. However, the SWTP can only treat a maximum of 30-35 MGD due to limitations in the raw water pumping system.

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<sup>2</sup> Based on data from TCEQ Drinking Water Watch database (<https://dww2.tceq.texas.gov/DWW/>) on 3/30/2022

Raw water is first diverted from the Neches River at Bunn's Bluff to the Beaumont Water Canal (Figure 1). The SWTP is not equipped to handle brackish water, so this diversion serves as a buffer from hurricane-driven saltwater encroachment. Water in the canal flows south, parallel to the Neches for about 3 miles to Lawson's Crossing. The City has a raw water pumping station at Lawson's Crossing that transfers the raw water further south to the SWTP in a 48-inch diameter main. This raw water main sits untethered in the bottom of Lawson's Canal.



*Figure 1. Map of the SWTP intake process.*

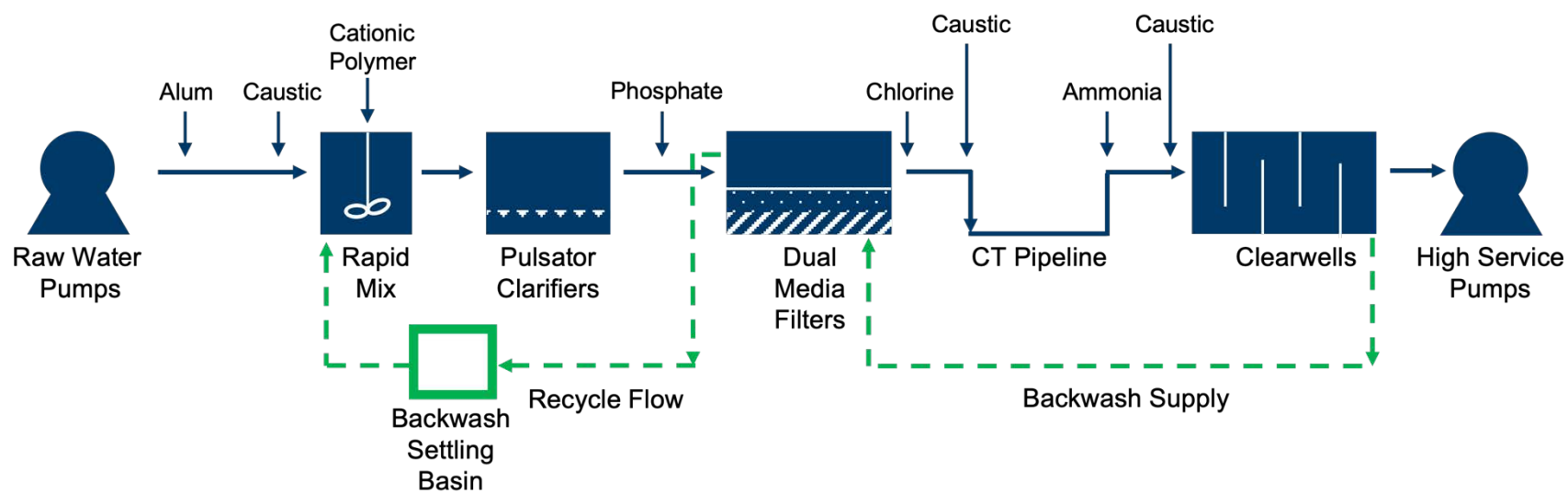
Upon arrival at the SWTP, raw water is first dosed with a coagulant (alum) and caustic before entering two parallel rapid mix basins. There is no pre-oxidation chemical added to the raw water. Polymer is added in each rapid mix basin. The water then flows from the rapid mix basin to a flume connected to the 5 Pulsator® clarifier basins. The Pulsator® is a pulsed sludge blanket clarifier. The sludge formed during flocculation is made up of an expansion mass. Water, that has coagulated beforehand, arrives from the bottom of the clarifier basins, and flows through this sludge blanket to emerge clarified at the top of the settling tank. The expansion of the sludge bed is controlled with the help of pulsating operation.

Following clarification, water is dosed with polyphosphate for sequestering of iron and manganese since there is no pre-oxidation chemical added to facilitate removal of these metals. The water then flows to the 10 parallel filters. Chlorine and caustic are dosed in the filter effluent and enters a length of pipe used

for inactivation (disinfection) credit. CT (concentration x time) values are used to determine the amount of inactivation credit achieved. CT is calculated by multiplying C (the concentration of free chlorine or other disinfectant in mg/L) by T (the disinfection contact time in minutes). Ammonia and caustic are dosed as the water enters two parallel clearwells. Five high service pumps send the water into the distribution system and two dedicated backwash pumps to backwash the filters.

Figure 2 shows a process flow diagram for the SWTP.

Figure 2. Process flow diagram for the Pine Street SWTP.



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## Water Quality Relevance

Typical water quality parameters that can be used to evaluate the performance of surface water treatment processes are described in this section. The importance of each water quality parameter is described below. In the Treatment Process Evaluation section, water quality, process design, and operational details are described for each unit process as defined in

Figure 2.

### pH and Alkalinity

Waters with higher pH and alkalinity values often require pH depression to reduce coagulant doses required for effective coagulation. Alkalinity influences the ability to change pH and in turn, the ability to remove total organic carbon (TOC) during the coagulation process.

### Turbidity

Direct particle count can be a very expensive analysis for drinking water utilities. As such, turbidity is more commonly used to measure the particle concentration in water. Rain events can increase sediment and particulate loading into surface waters and cause turbidity spikes. Current regulations applicable to the SWTP require the filtered water turbidity to remain below 1.0 NTU at all times and less than 0.3 NTU for 95% of the samples in a month. Turbidity is regulated to remove microbial pathogens in the filter effluent for surface water treatment plants for both the individual filter effluent and the combined filter effluent. Microbial pathogens can use particles to shield themselves from disinfectants, such as chlorine that is used by the City, and persist into the distribution system. Turbidity is removed by coagulation/flocculation/ sedimentation and filtration at the SWTP.

### Iron and Manganese

Iron and manganese are regulated metals that can cause discolored water that may result in customer complaints if not appropriately managed in the SWTP. Iron and manganese have secondary maximum contaminant levels (SMCLs) of 0.3 mg/L and 0.05 mg/L, respectively. Both metals can increase solids waste generation and exert some demand on oxidation and disinfection processes, resulting in higher required doses to provide the acceptable water quality. Iron and manganese can be removed through conventional surface water treatment with adequate pre-oxidation prior to filtration.

### Ammonia, Nitrite and Nitrate

Nitrogen, along with carbon and phosphorus, is a primary nutrient for the growth of microorganisms. Ammonia, nitrite and nitrate are inorganic forms of nitrogen that can be present in source waters. Nitrite and nitrate both have primary MCLs of 1 mg/L (as N) for nitrite, and 10 mg/L (as N) for nitrate. If free ammonia is present in treated water, nitrite and nitrate can also form in the distribution system due to nitrification.

## Total Organic Carbon

Total organic carbon (TOC) is a surrogate measurement for the organic matter in water and drives disinfection byproduct (DBP) formation. There are regulations for removal/reduction of TOC based on the source water quality to reduce DBP formation. Typically, a majority, if not all, of the TOC in a surface water is dissolved and will form higher concentrations of DBPs if untreated. TOC is removed through the coagulation/ flocculation/ sedimentation and filtration processes at the SWTP.

## Treatment Process Evaluation

### Raw Water Quality

As described above, the SWTP receives water from the Neches River. A summary of the historical raw water parameters is shown in Table 2. This data was analyzed in-house at the SWTP and reported from February 2018 to November 2020. No other raw water data is available after this date. Most notably, iron's 25<sup>th</sup> percentile concentration is the same as the SMCL of 0.3 mg/L while the manganese 75<sup>th</sup> percentile concentration is below the SMCL of 0.05 mg/L. Color ranges from 30 to 169 color units (CU). This range is higher than the color SMCL of 15 CU. Turbidity has a relatively small range of 13.2 to 32.7 NTU. It should be noted that this data does not include 2017, which is when Hurricane Harvey would have disrupted these parameters, especially turbidity.

Table 2. Neches River raw water parameters (2016 – 2021)

Parameter	Minimum	25th Percentile	Median	75th Percentile	Maximum	Count
Aluminum (mg/L)	0.00	0.01	0.01	0.04	0.43	48
Calcium (mg/L)	5.6	7.2	8.0	8.4	19.0	47
Chloride (mg/L)	10	19	21	23	46	48
Color (color units)	30	52	61	69	169	48
Conductivity (µS/cm)	85	123	130	137	222	42
Copper (mg/L)	0.00	0.00	0.00	0.06	0.24	46
Hardness (mg/L as CaCO <sub>3</sub> )	17	28	31	33	39	48
Magnesium (mg/L)	1.90	2.40	2.70	3.20	4.40	42
pH (standard units)	6.04	6.50	6.60	6.80	7.07	48
Sulfate (mg/L)	5	9	11	14	32	42
Temperature (C)	15	21	24	29	33	48
Total Alkalinity (mg/L as CaCO <sub>3</sub> )	12	20	23	25	32	48
Total Iron (mg/L)	0.13	0.30	0.50	0.64	1.58	47
Total Manganese (mg/L)	0.01	0.02	0.02	0.03	0.11	46
Total Organic Carbon (mg/L)	5.1	5.9	6.8	8.4	12.8	45
Turbidity (NTU)	13.20	18.95	22.00	25.00	32.70	48

### Influent Pipeline

Raw water enters the plant through a 48-inch diameter pipeline at the northern end of the property. As described further below, alum and caustic are dosed prior to rapid mix but no pre-oxidant is currently used on the raw water to oxidize iron and manganese.

The raw water pH and total alkalinity medians were 6.6 standard units (SU) and 23 mg/L as  $\text{CaCO}_3$  respectively for the data available (Figure 3). As shown in the Figure, raw water pH can occasionally drop to values less than 5.0 SU. It should be noted that the bulk of this data is from 2020 and was taken from recorded grab samples.

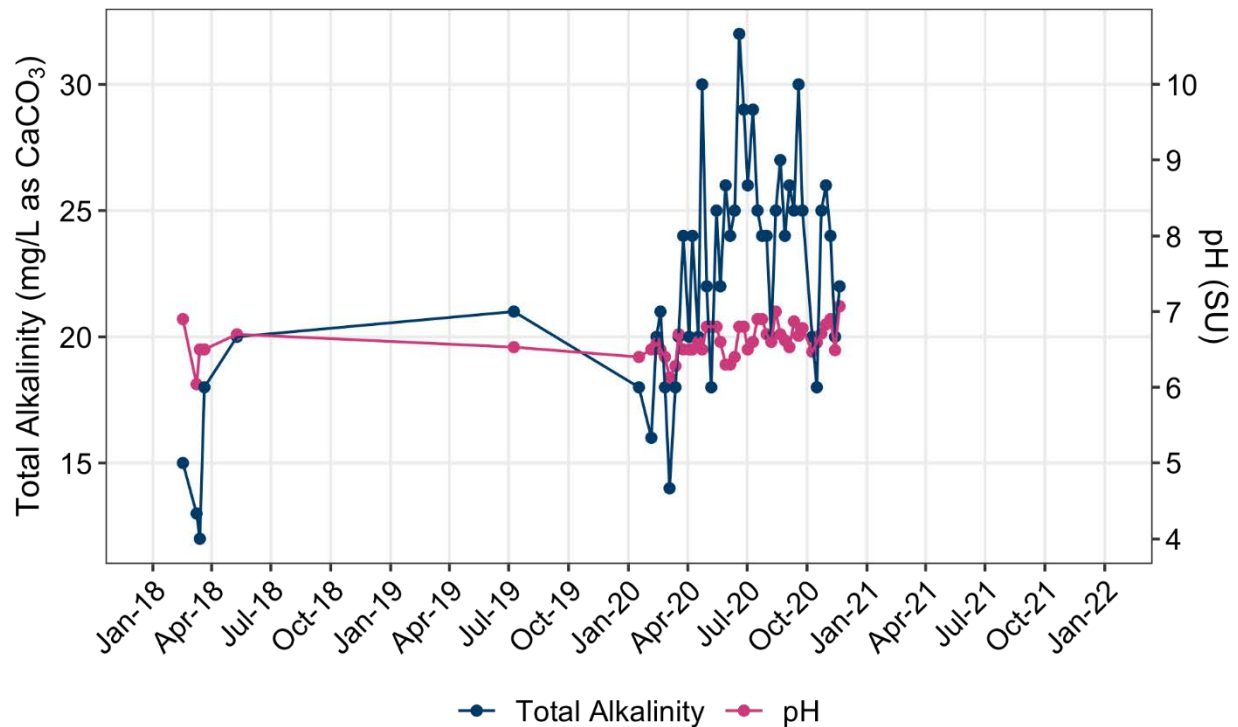


Figure 3. Raw water total alkalinity and pH.

**RECOMMENDATION #1:** Corona recommends installing online pH analyzers to monitor pH in real time to facilitate an improved monitoring and response strategy for changes in raw water pH.

Alum and caustic are both dosed prior to rapid mix. Alum data was provided for February 2019 to November 2021 and ranged from 40 mg/L to 152 mg/L with a median dose of 66 mg/L (Figure 4). Alum is used as a coagulant to help settle dissolved particles out of the water. Jar tests are performed daily at the SWTP to determine the appropriate alum and caustic doses.

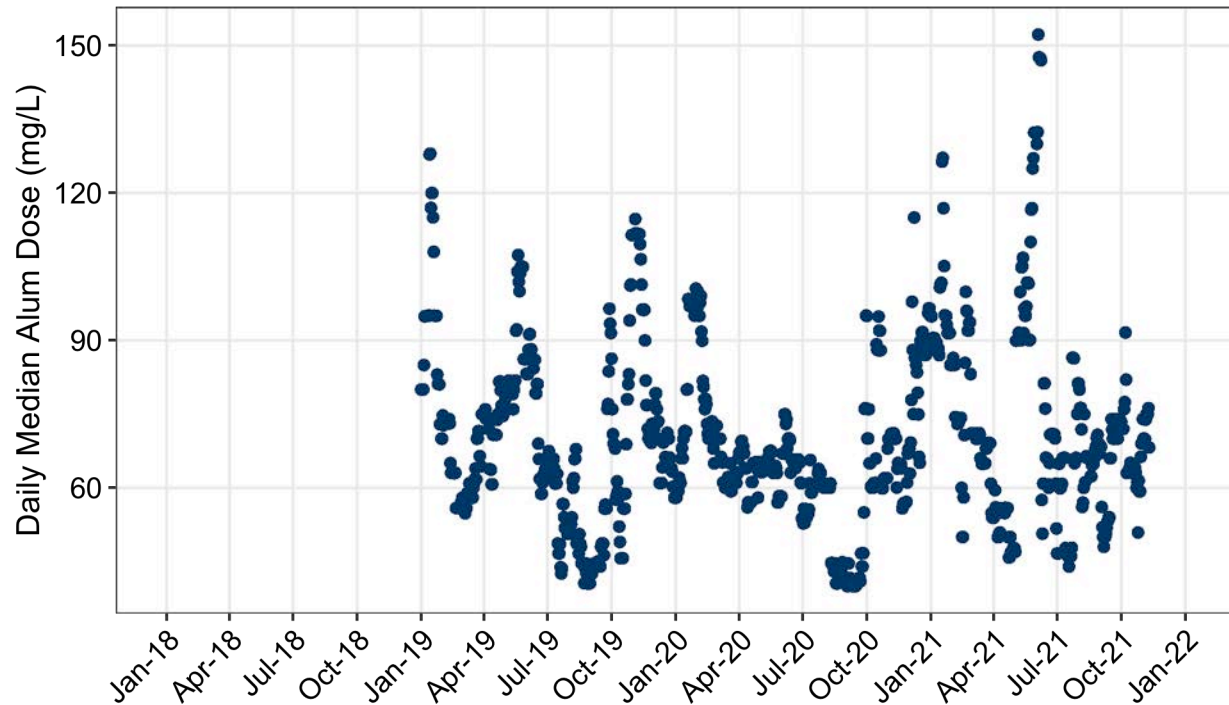


Figure 4. Daily median alum doses from 2019 to 2021.

Caustic is added to raise the pH at three locations in the treatment process: prior to rapid mix, filter effluent, and just before entering the clearwell. Caustic doses are dependent on the raw water pH and the alum dose. Before rapid mix, caustic is dosed at a median of 7.68 mg/L. Doses ranged from 0 mg/L to 36 mg/L from 2019 to 2021 (Figure 5).

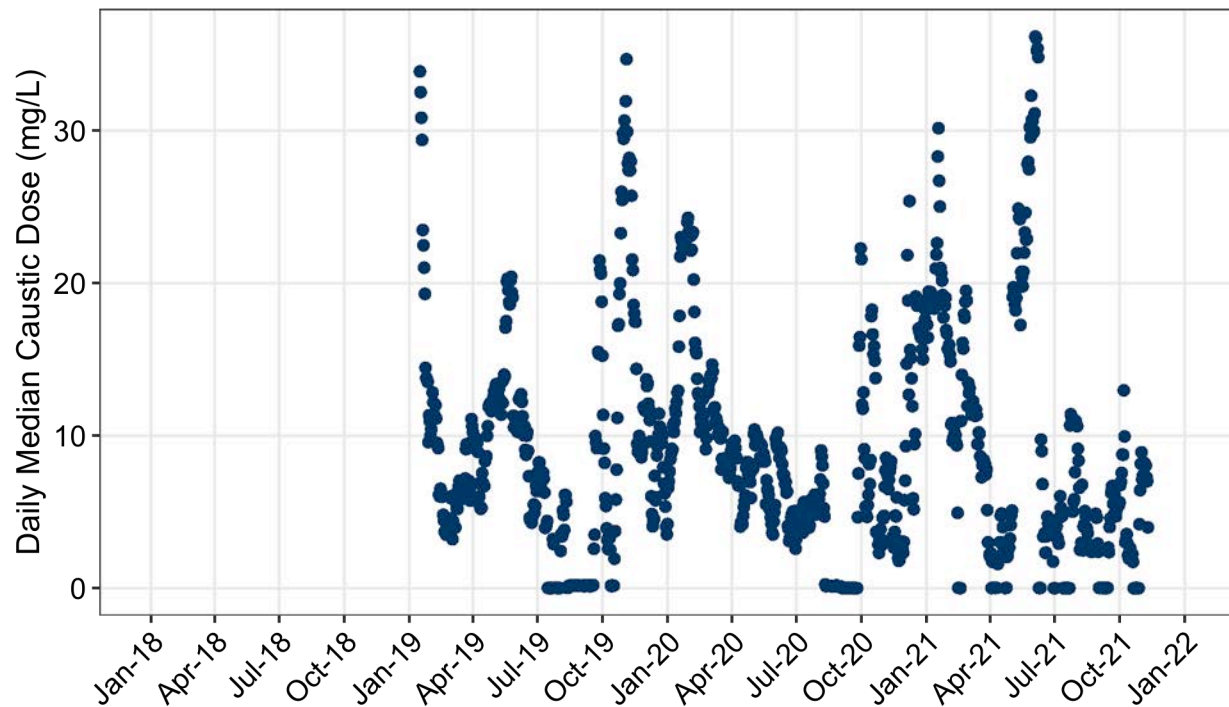


Figure 5. Daily median caustic doses injected prior to rapid mix.

#### Rapid Mix

The rapid mix basin is located between settling basins 3 and 4. Flow is split between two parallel basins and dosed with two separate polymer pumps, but only one is in service at a time. After mixing, the water is discharged to a common effluent channel to travel to the clarifier basins.

Polymer alters the chemical charge and promotes particle growth for sedimentation. Too much or too little polymer can cause inadequate floc formation and may hinder sedimentation. The median polymer dose is 0.3 mg/L with a spread of 0 to 1 mg/L (Figure 6). Some data showed doses higher than 40 mg/L in May and August 2020, but these were omitted for this analysis because they are presumed to be erroneous data points. Figure 6 also shows that there is no difference between the polymer feeds from the two feed pumps.

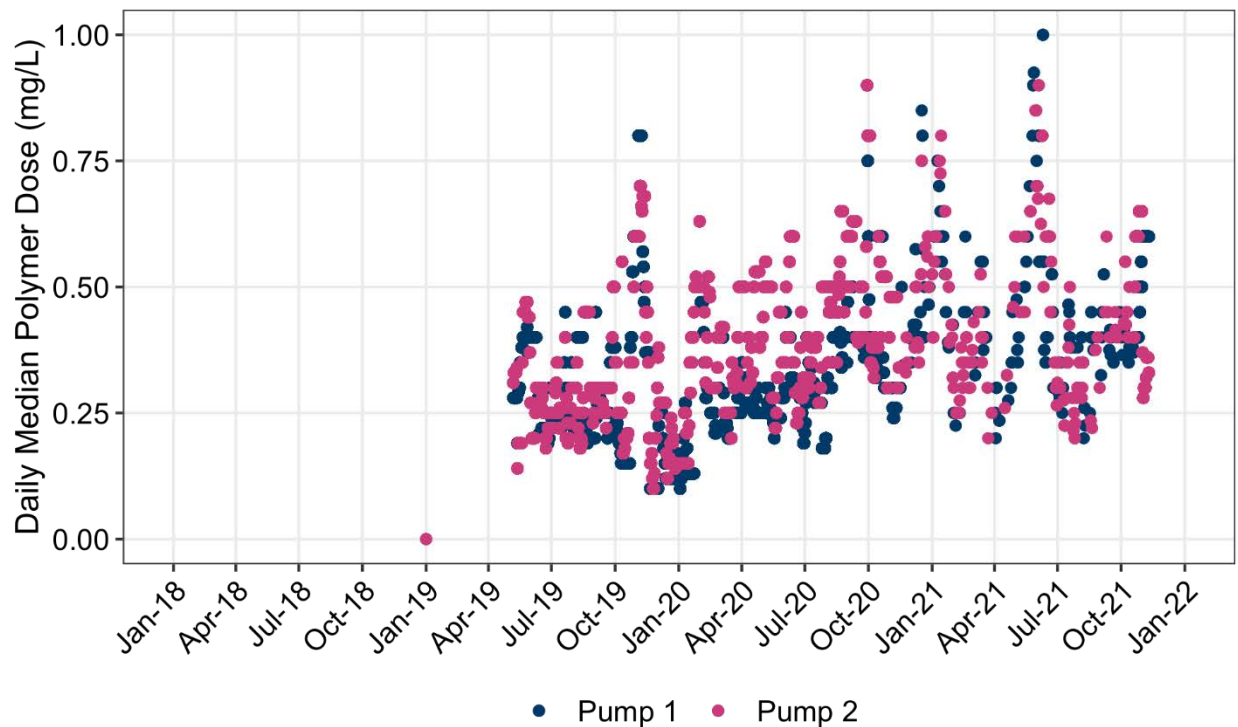


Figure 6. Daily median polymer doses for both pumps.

#### Clarification

Water flows from the Rapid Mix basin into a flume that feeds 5 Pulsator® basins. In this process flocs created from the previous chemical additions are separated from the water through sedimentation. Water enters from the bottom of the basin and passes through a sludge layer before rising to the top. Two clarifiers have clogged sludge drains and require a contractor to clean them out. Clarifiers require frequent cleaning, and the clogged sludge drains indirectly affects performance due to delayed maintenance.

**RECOMMENDATION #2:** Corona recommends repair or replacement of these sludge drains to restore the units back to normal operations for regular maintenance of the basins.

Clarified water data was available prior to 2016, with the exception of some current manganese readings (discussed later). After a site visit in early December 2021, Corona learned that monitoring of turbidity for the clarified water had been discontinued due to a citation from TCEQ related to a minor discrepancy in the data although this monitoring is not required for regulatory compliance purposes. There is no regulatory requirement to monitor clarified water unless TCEQ mandates it. Though turbidity regulations were established based on microbial protection, turbidity may also be used as a measure of unit process performance for other water quality characteristics, which could result in discolored water in the distribution system. For example, monitoring turbidity can help check that chemicals are being properly dosed and will not inhibit filter performance downstream. (see AWWA partnership for safe water). Additionally, the future addition of  $\text{ClO}_2$  will add more particulate iron and manganese. This will require optimized clarification to reduce the filter load downstream.

Upon Corona's recommendation during the site visit, the SWTP responded by monitoring settled water basin turbidities starting in January 2022.

**RECOMMENDATION #3:** Corona recommends the City begin monitoring and recording settled water parameters, including turbidity and manganese, to ensure water quality and individual clarifier performance.

Clarifier effluent is dosed with polyphosphate before entering the filters to sequester manganese. The SWTP uses Sterling CP 2060D, a 25:75 ratio of ortho to polyphosphate, as  $\text{PO}_4$ . In May 2021, the product dose was quadrupled from 0.5 mg/L to 2 mg/L as product (Figure 7). Phosphate was increased to sequester more manganese and reduce discolored water in the distribution system. The SWTP has been proactive in addressing discolored water concerns by increasing phosphate dose. Discolored water complaints will be further discussed in the Customer Complaints section.

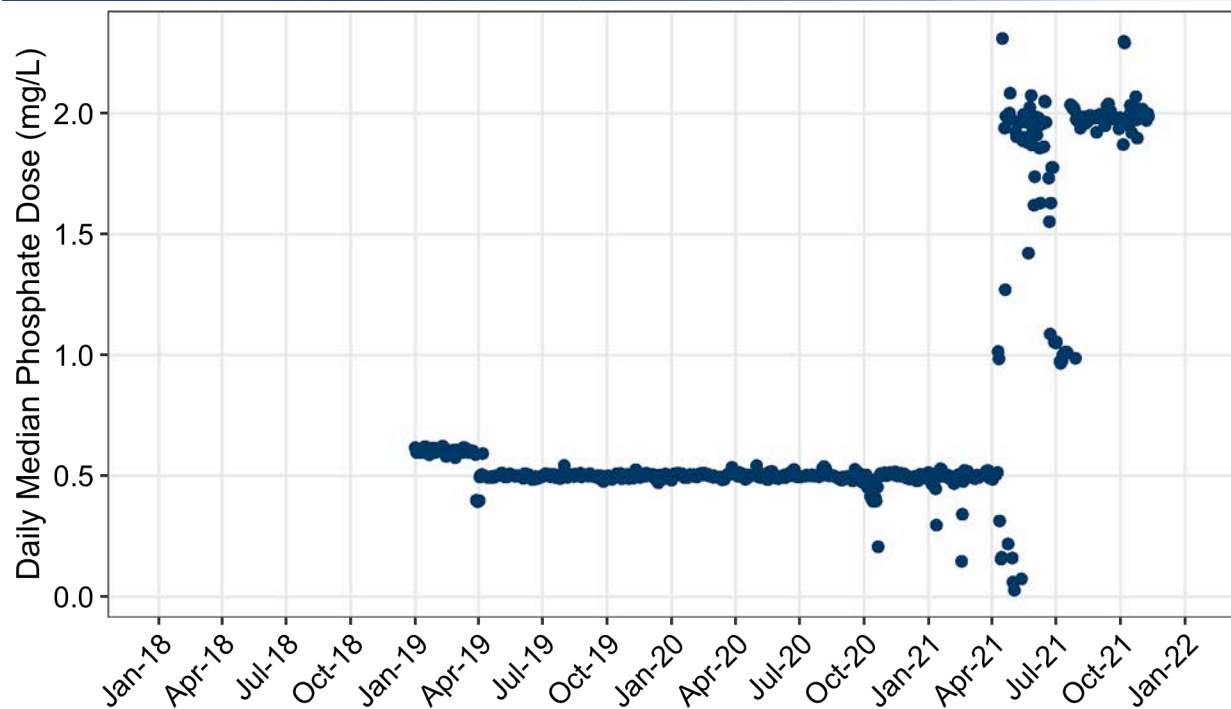


Figure 7. Polyphosphate historical dosing.

#### Filtration

Filters are used to remove residual turbidity from the clarified water. The SWTP has 10 dual media filters consisting of 30" of anthracite and 12" of sand. After a certain amount of run-time, head loss, or increased turbidity in the effluent, filters are backwashed. At the SWTP, filters are backwashed with water provided from dedicated pumps on the clearwell effluent.

As shown in Figure 8, historically, filter flows varied depending on the filter. It is unusual to have such stratification of flow rates across filters, with some filter flows (i.e., Filter 2) nearly double the flow of others (i.e., Filter 5).

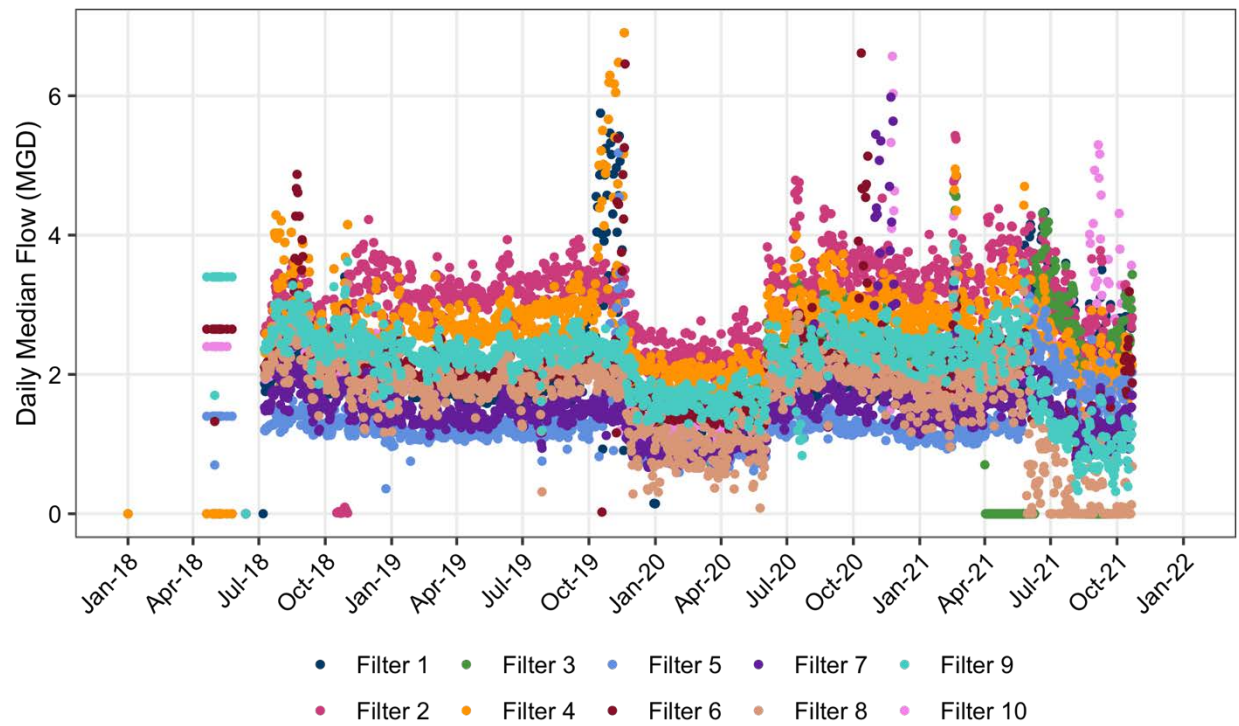


Figure 8. Filter flow rates MGD.

**RECOMMENDATION #4:** Corona recommends equalizing the flow across all filters to prevent disproportionate wear and tear on filters processing more water.

The median raw and settled water turbidities were 26 NTU and 0.4 NTU respectively for the data provided (Figure 9). It should be noted that settled water turbidity data was only available for 2016. Filters further reduced turbidity to less than 0.3 NTU, the regulatory threshold (shown as the red dashed line in Figure 9). The median combined filter effluent (CFE) turbidity was 0.09 NTU, though CFE turbidity exceeded 0.3 NTU several times between 2017 and 2021. Since there is potential of high turbidity events from hurricanes and other weather events, optimizing treatment will help the SWTP meet the 0.3 NTU limit reliably when treating extremely turbid waters. In addition, the filters do not have the ability to filter-to-waste. This can impact filtered water turbidity and manganese release to the distribution system when bringing filters online following a backwash.

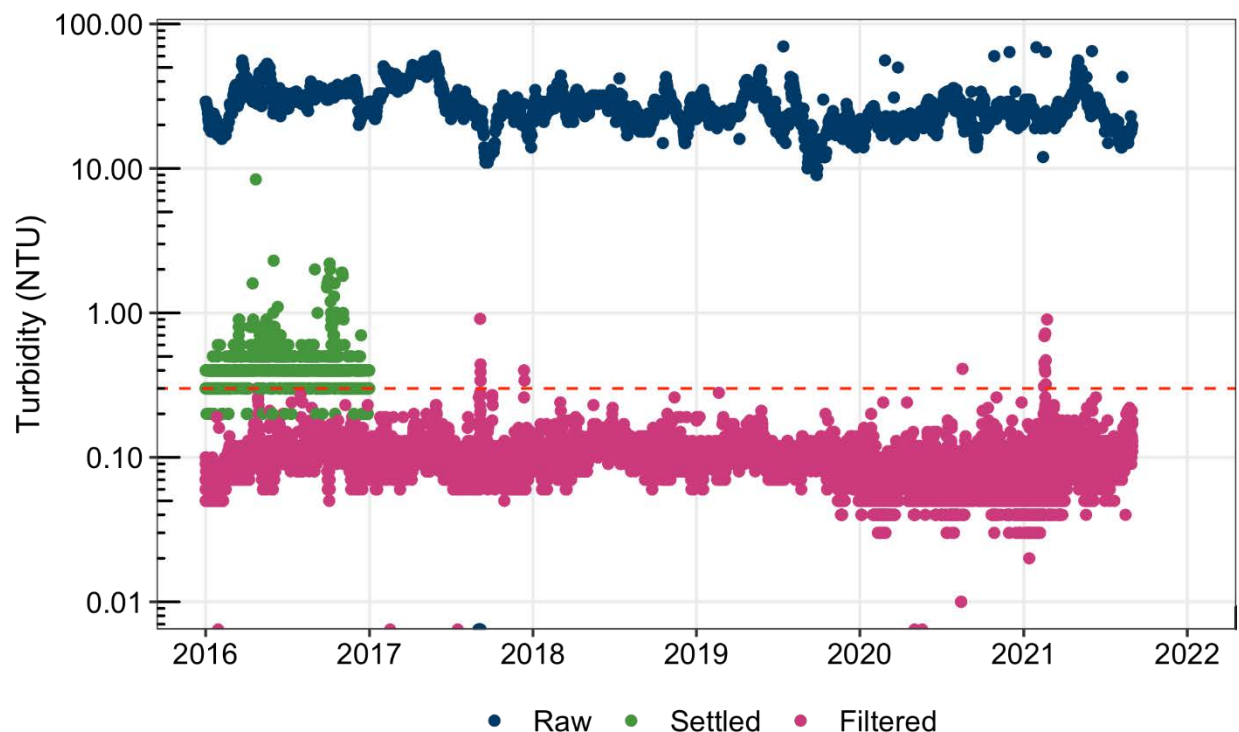


Figure 9. Turbidity measurements for raw, settled, and filtered water.

**RECOMMENDATION #5:** Corona recommends setting a turbidity goal of <2.0 NTU in settled water and <0.1 NTU in the filter effluent to treat the water more conservatively, and as recommended by AWWA's Partnership for Safe Water Program and Texas Optimization Program.

**RECOMMENDATION #6:** Corona recommends installing filter-to-waste capability at the SWTP to better facilitate improved finished water turbidities to meet optimization goals, as well as to reduce manganese release from the filter media upon return to service.

### Chlorine Contact Time Pipeline

After filtration, water is immediately dosed with caustic and then chlorine. A free chlorine residual is carried in the main line between the filters and clearwell for inactivation of pathogens. The inactivation credit achieved is based on the contact time, free chlorine residual, pH, and temperature of the water.

As shown in Figure 10, immediately after filtration, the median caustic dose was 11.5 mg/L until July 9, 2021 for a target CT pH of 6.3 on average. The dose jumped to a median dose of 27.4 mg/L from July 2021 to September 27, 2021, because caustic dosing was turned off downstream (due to repairs), prior to the clearwell. The caustic dose then dropped to a median dose of 8.18 mg/L when dosing resumed at the clearwell influent.

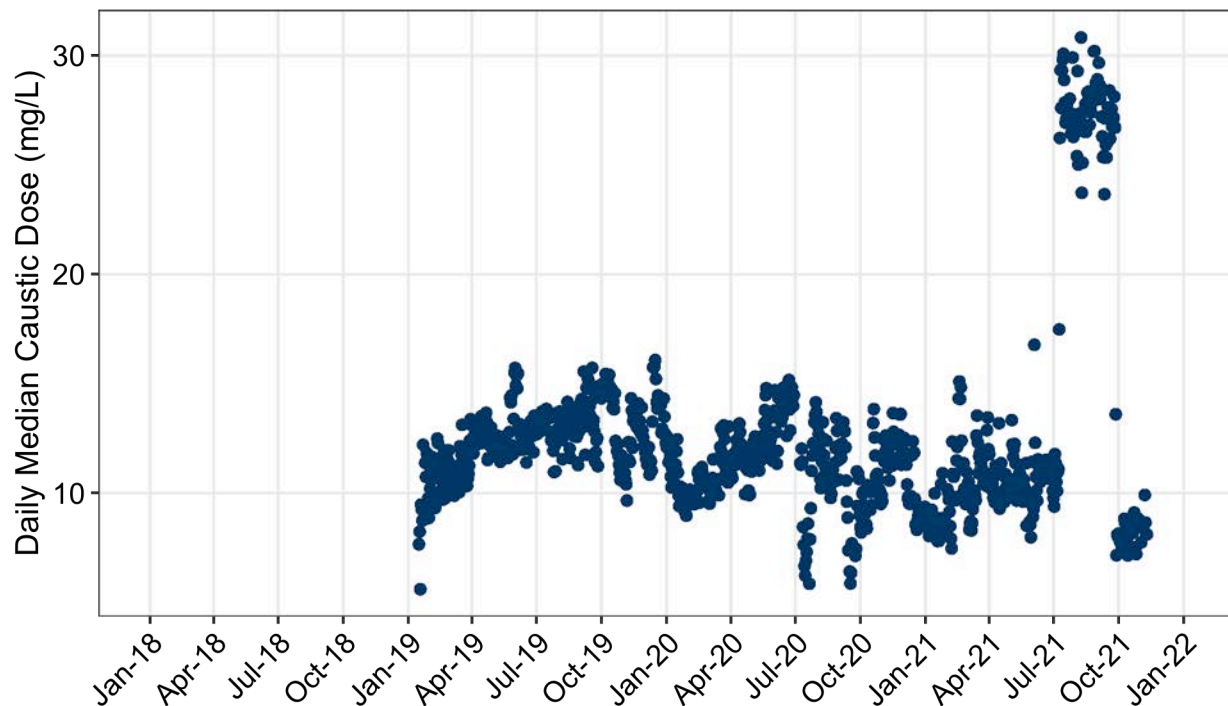
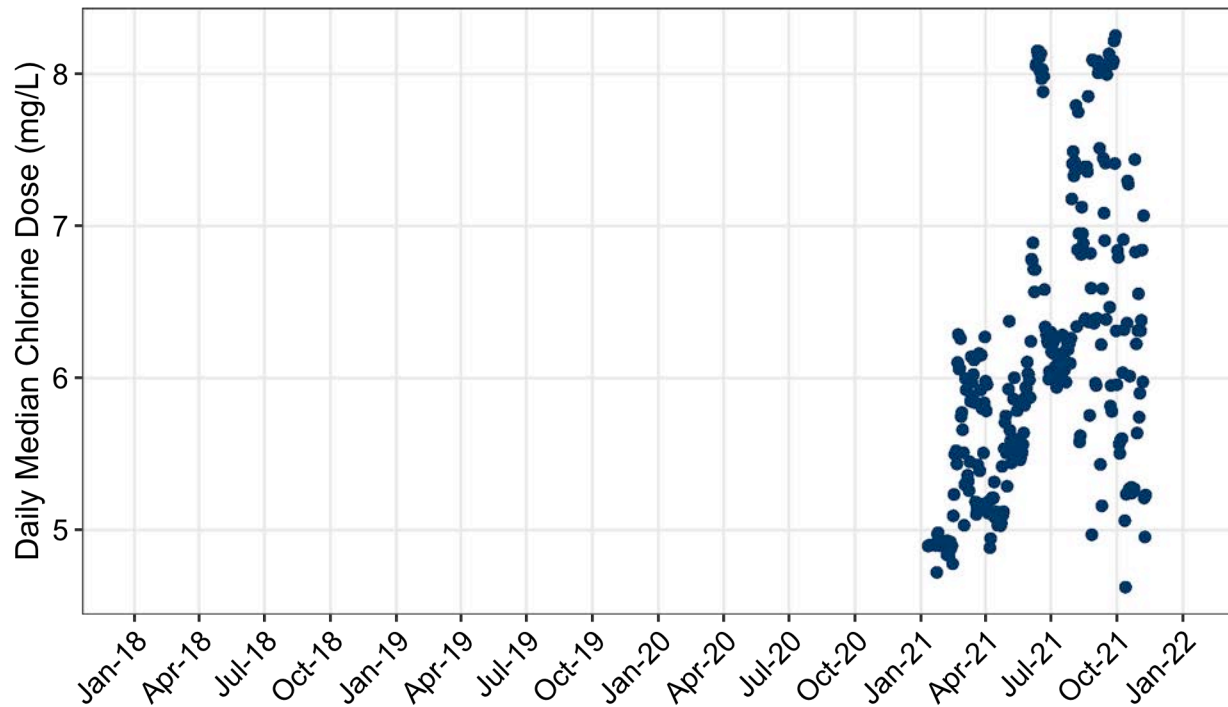


Figure 10. Daily median caustic doses injected immediately following filtration (at the start of the CT pipeline).

Chlorine dosage data was provided from January 2021 to November 2021. From January 2021 to July 2021, chlorine doses steadily increased until August 2021 (Figure 11). Chlorine doses peaked around the same time the post-filtration caustic doses peaked in summer 2021. The median chlorine dose for the time period of data provided was 5.9 mg/L. There were 4 days where the dose ranged from 14 to 124 mg/L. These were eliminated as outliers or instrumentation errors.



*Figure 11. Daily median chlorine dose injected immediately following filtration (at the start of the CT pipeline).*

Just prior to entering the clearwell, water is dosed again with caustic and then ammonia to form chloramines. The median pre-clearwell caustic dose from 2019 to 2021 was 13.4 mg/L (Figure 12). While there is some variability over the years, it is not as drastic as was seen in the filter effluent dose. As noted above, caustic was not dosed immediately prior to the clearwells during summer 2021 due to repairs but resumed around October 2021.

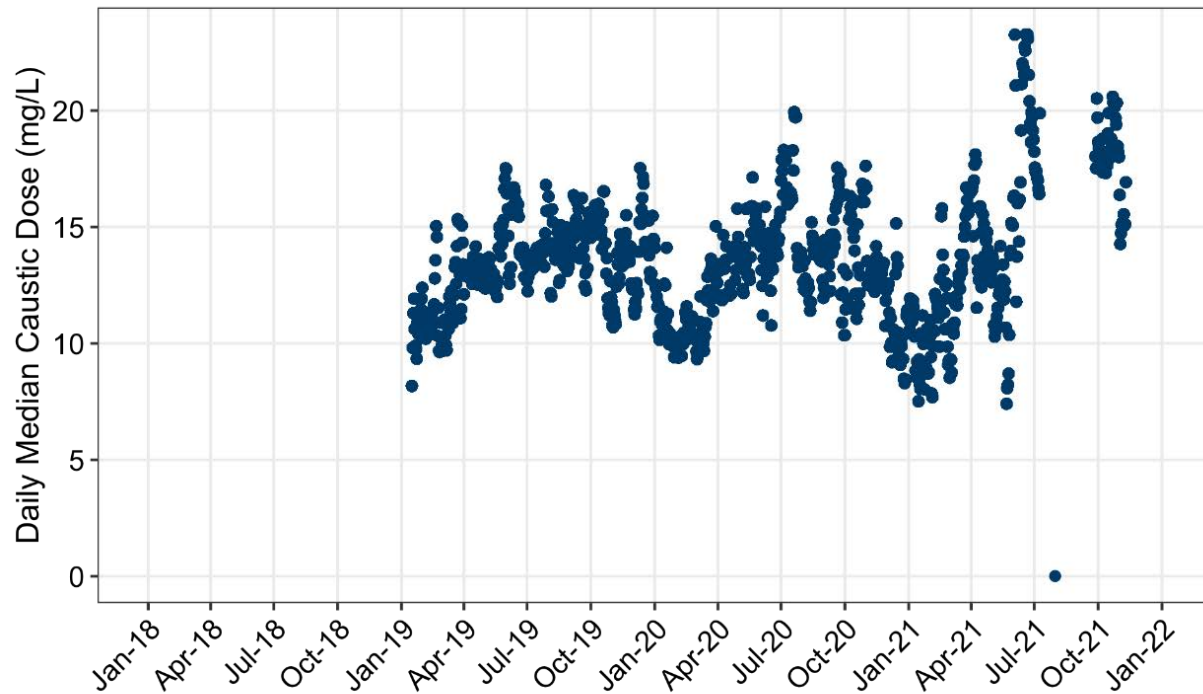


Figure 12. Daily median caustic doses injected just before the clearwell (end of CT pipeline).

The median ammonia dose from 2019 to 2021 was 1.12 mg/L (Figure 13).

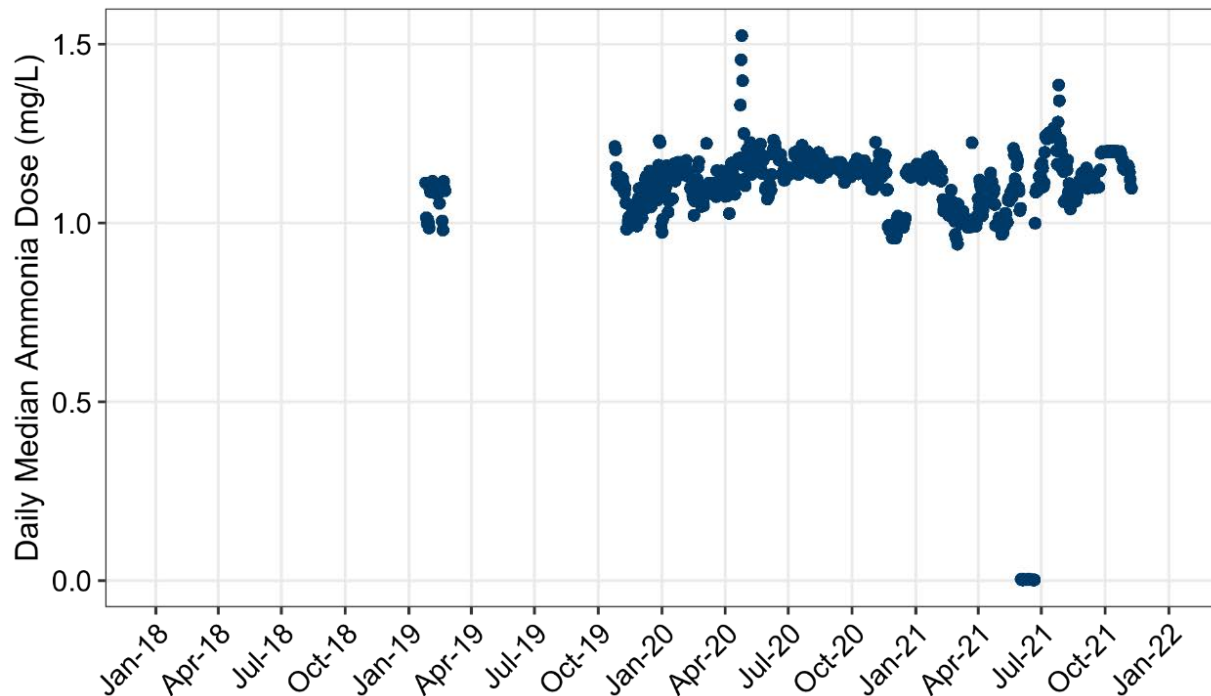


Figure 13. Daily median ammonia doses injected prior to the clearwell (end of CT pipeline).

#### Clearwells

##### Disinfection

The City achieves additional disinfection in the clearwells with chloramines, and the overall disinfection process is effective for meeting the required CT. Daily disinfectant residuals and free ammonia data was provided from 2021 onwards. Figure 14 shows that the median monochloramine residual is 1.9 mg/L at the point of entry. The median free ammonia entering the distribution system is 0.028 mg/L as N. However, Figure 14 shows there are several recordings of free ammonia entering the distribution system above the recommended threshold level of 0.1 mg/L for prevention of nitrification. While this indicates there is little free chlorine to enter the system and form DBPs, higher free ammonia may result in nitrification and an overall loss in disinfectant residual.

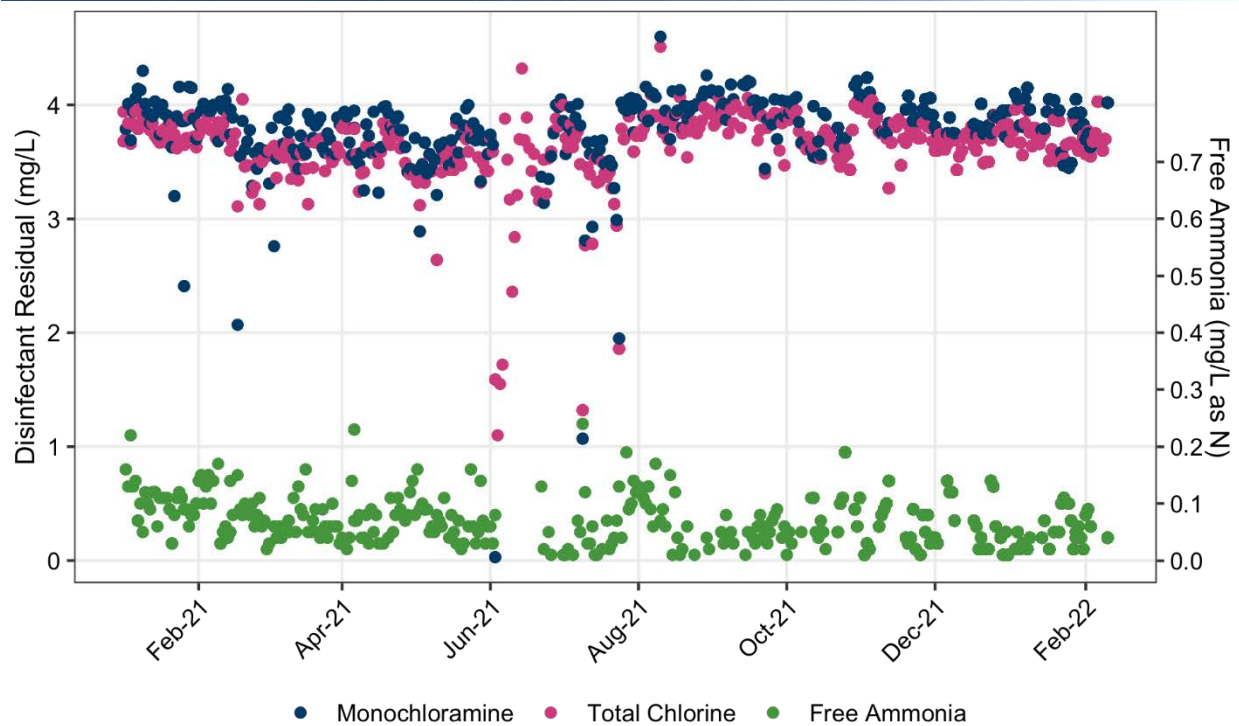


Figure 14. Disinfectant residuals leaving the SWTP.

#### Finished Water Quality

Finished water had a median pH of 8.57 and alkalinity of 20 mg/L as  $\text{CaCO}_3$  based on data from 2018 to 2020. The two caustic additions in the CT pipeline prior to the clearwell raised the pH above 8.

The TOC removal ratio was calculated by dividing the percent of TOC removed by the required percent TOC removal according to the Step 1 Rule (Figure 15). The minimum Step 1 TOC removal ratio was greater than 1.0, indicating compliance with this requirement was consistently achieved at the Pine Street SWTP during this period.

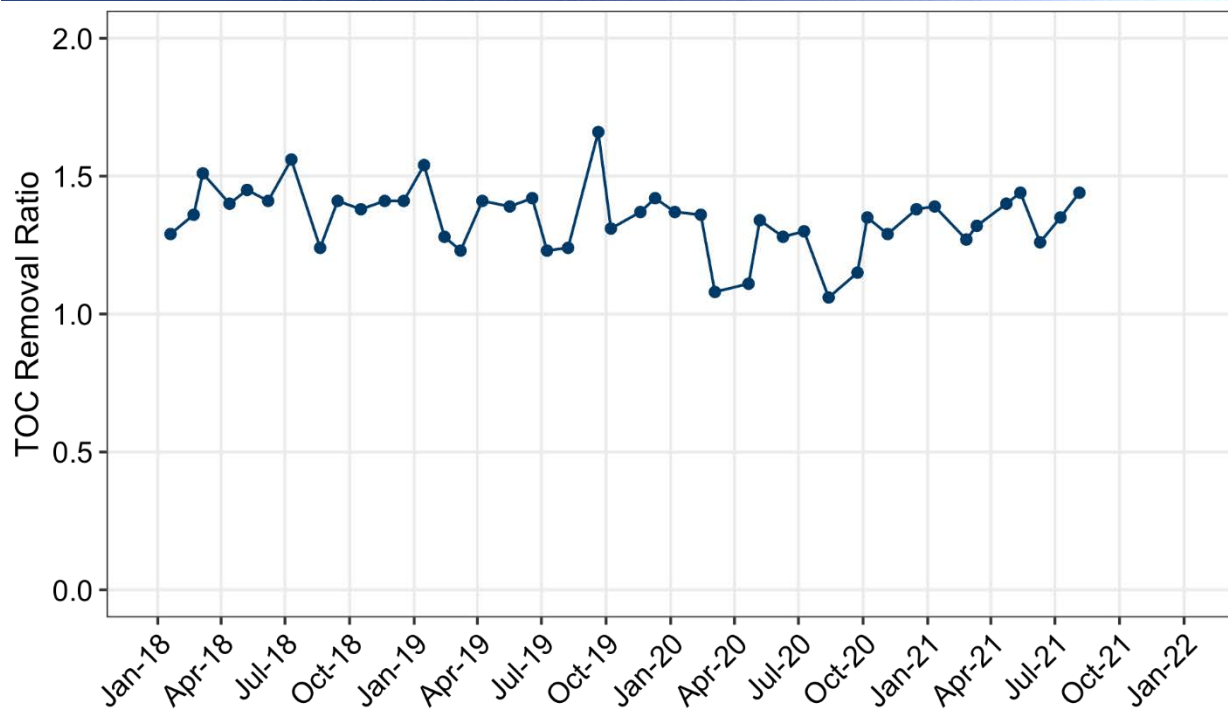


Figure 15. TOC removal at the SWTP.

#### Backwash Settling Basin

Filter backwash wastewater is sent to a settling basin, then the supernatant is recycled back into the rapid mix basin for treatment. The coagulant dosed in the raw water main is inclusive for the flow rate from the recycled water stream. Sludge is removed as needed from the settling basin. Data for the recycle flow rate was only available for October 2021. To calculate recycle flow rate, this recycle flow was paired with October 2020 production. The recycle flow rate ranged from 1.64% to 0.59%. Note that the time periods of the data provided for plant production and recycle flow do not overlap.

**RECOMMENDATION #7:** Corona recommends ensuring recycle flow data is continuously monitored and recorded and historical data is available for review and analysis.

#### Manganese Treatment at the SWTP

While Corona staff were onsite in early December 2021, manganese samples were collected to compare manganese readings from the SWTP's analyzer and Corona's DR600. Hach method 8149 was used – sufficient for in-house process control testing. Samples were taken from a raw water tap, a settled water tap, combined filter effluent (CFE) tap, backwash water collected during a filter backwash as the water entered the backwash settling basin, recycled backwash water collected from a tap, and high service finished water from a tap. Results from these total manganese readings are listed in Table 3.

Based on the data shown in Table 2, clarification removes about 65% to 70% of the raw water manganese. However, manganese is accumulated in the filters as the manganese concentration increases by about 0.02 mg/L in the CFE. Finally, some manganese is acquired in the clearwell as evidenced by another 0.007-0.015 mg/L increase in the high service pump effluent (finished water). Though about 42% of manganese

was removed from raw water to treated water, the final manganese concentration was still over the SMCL of 0.050 mg/L. The backwash waste had the highest concentrations of manganese, however 65% to 70% of this was settled out of the water before being recycled to rapid mix.

*Table 3. Total manganese sample comparison between Corona and Pine Street SWTP.*

Sample Location	Corona Measured Total Manganese (mg/L)	SWTP Measured Total Manganese (mg/L)
Raw	0.099	0.115
Settled	0.035	0.035
CFE	0.050	0.052
Backwash Water	0.134	0.166
Recycle	0.047	0.050
High Service	0.057	0.067

The onsite data verifies some of the manganese data reported from 2019 to 2020 (Figure 16). Manganese concentrations for settled water were similar to the onsite data with a median of 0.046 mg/L. However, compared to the raw water manganese reported from 2020, manganese increased in the settled water from a raw water median of 0.02 mg/L. Like Corona's grab samples in December 2021, manganese concentrations increased from filtered water (green) to high service water (blue). This indicates sludge has collected at the bottom of the clearwells and may be contributing manganese to the finished water. The City has a project underway to clean sludge and repair baffles in the clearwells. It should be noted that the data in Figure 16 has omitted 6 manganese outliers greater than 0.25 mg/L to see the data better (4 points from settled water and 2 points from high service). It should also be noted that manganese was only monitored, recorded, and reported from 2019 to 2020.

Manganese monitoring was restarted in November 2021, but monitoring is not occurring at all of the recommended locations and frequency.

**RECOMMENDATION #8:** Corona recommends consistent manganese monitoring and recording as discolored water is a recurring problem for the City, as well as weekly manganese monitoring at the high service pumps tested by an external laboratory for confirmation.

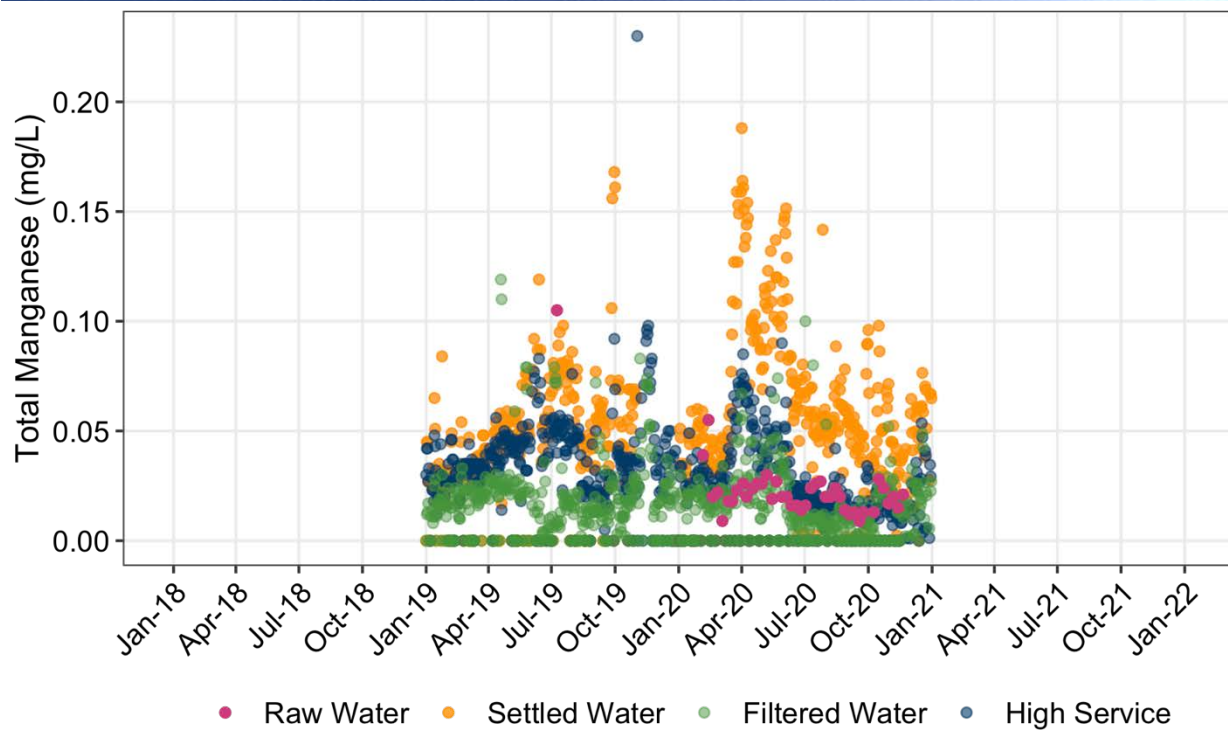


Figure 16. Historical total manganese at different sample locations.

Manganese monitoring will provide insight into accumulation and/or removal through each process unit as well as finished water quality provided to the distribution system. It will help verify any spikes in discolored water complaints and isolate where the problem stems from for faster resolution. For example, if manganese is reported to be higher in the clearwell effluent than the filter effluent for a few consecutive days, it might indicate the clearwells have accumulated manganese and need to be cleaned again.

**RECOMMENDATION #9:** Corona recommends daily review of manganese levels through each process unit of the SWTP to ensure there is no trend of increasing manganese levels through any process unit.

Raw water may contain both particulate and dissolved forms of manganese. Furthermore, some dissolved manganese may be oxidized throughout the plant by means of aeration, biological activity in the filters, and chlorination. Additionally, when an oxidant like chlorine dioxide is added upstream, it will be important to optimize the filter backwash frequency and duration as the filters will begin removing more manganese than it does today.

**RECOMMENDATION #10:** Corona recommends evaluating the filter backwash frequency and duration to maximize removal of manganese from the filters.

**RECOMMENDATION #11:** Corona recommends chlorine dioxide ( $\text{ClO}_2$ ) be tested as a pre-oxidant in the raw water ahead of alum application. This will convert dissolved iron and manganese to particulates which can be removed through the subsequent plant processes.  $\text{ClO}_2$  is optimal with a 2 to 3-minute contact time prior to coagulant addition. The site map below (Figure 17) shows a green star that indicates the potential location for  $\text{ClO}_2$  that may provide adequate contact time for the  $\text{ClO}_2$  to oxidize the metals.

Previously,  $\text{ClO}_2$  was briefly added to the filter effluent as an added CT benefit. However, this was quickly discontinued as iron and manganese were oxidized and caused discolored water. Using  $\text{ClO}_2$  in the raw water will allow iron and manganese to be removed in the clarifiers and filters and reduce the number of colored water episodes in the future with proper distribution system management.



Figure 17. Site map of the Pine Street SWTP and potential  $\text{ClO}_2$  injection point.

## Loeb Groundwater Treatment Plant

### Configuration and Process

In addition to the SWTP, the City blends groundwater from three wells at the Loeb Groundwater Treatment Plant (GWTP). The GWTP is rated at 17 MGD and a process flow diagram of the GWTP is shown in Figure 18. The site houses two, 5 MG ground storage tanks, one concrete and one steel. Chlorine and ammonia are dosed to form chloramines.

Based on a desktop corrosion analysis, Freese and Nichols recommended increasing the pH at the GWTP to reduce nitrification and improve chloramine stability. To achieve this, caustic dosing capability was added to the GWTP in April 2022. The caustic is dosed prior to water entering the ground storage tanks.

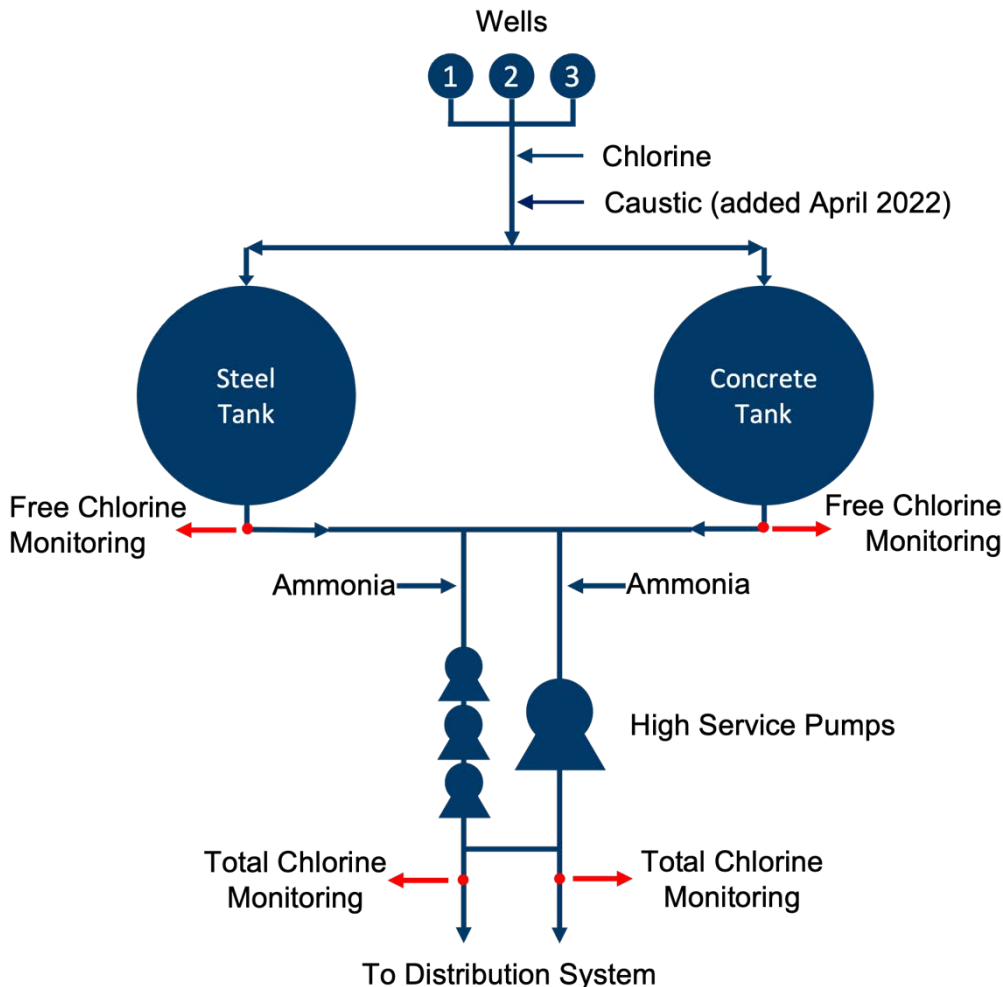


Figure 18. Well configuration at the GWTP

### Chemical Dosing

The wells were not running during Corona's site visit, so no samples were taken. Chemical injection, mixing, and monitoring locations were evaluated for adequate process performance and control. Currently, only one analyzer is used for free chlorine monitoring of each tank separately. So, the sample line must be switched back and forth depending on which tank is selected to monitor but the data that is recorded does not differentiate which tank the results represent.

There are two separate ammonia injection locations due to having two separate high service pumping trains. One injection point is selected based on which high service pump is in service. Due to the location of the ammonia injection points the backpressure on the ammonia feed pump varies based on the water level in the tanks. This is believed to result in a varying ammonia dose as the tank levels change.

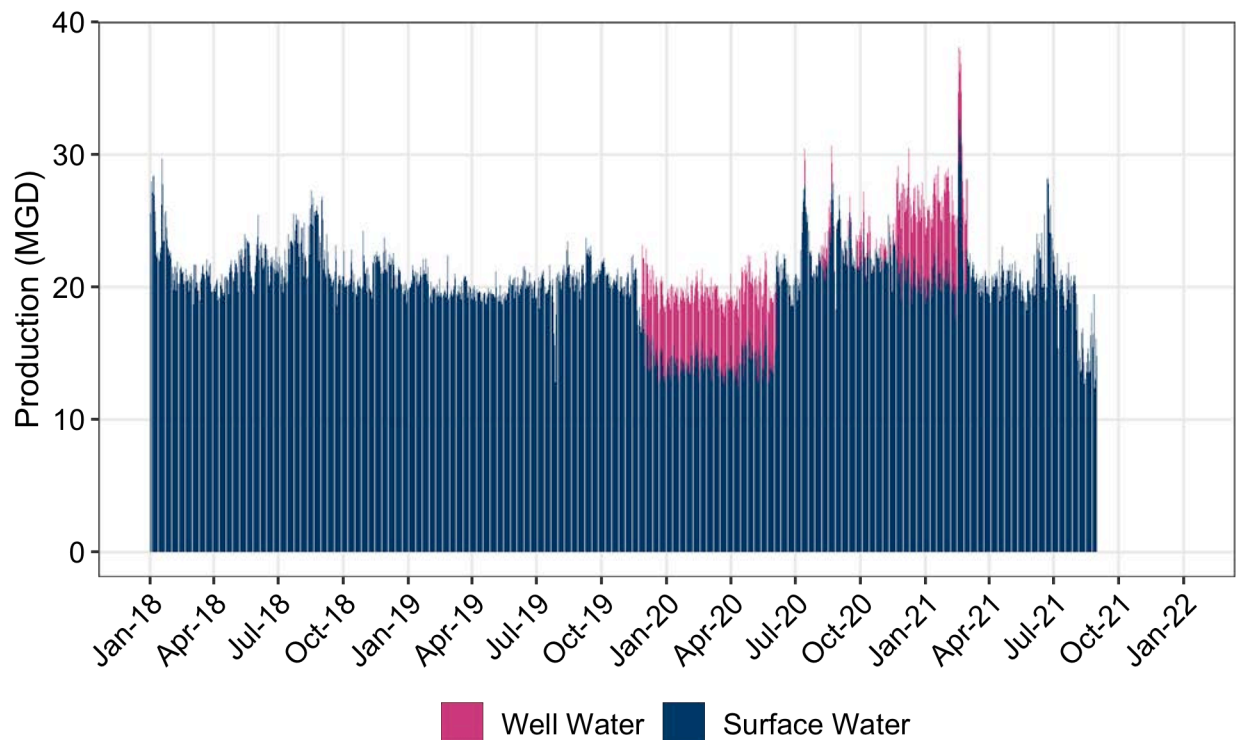
The ammonia dose injected is based on the free chlorine residual reading from the analyzer described above. This analyzer records free chlorine residual in one of the two storage tank effluents at any given time. However, the influent water to the high service pumps is a blend of varying proportions of water from the two storage tanks with differing chlorine residual levels. As such, the ammonia dose being injected for monochloramine formation is always sub-optimal. This is very likely the primary cause of observed nitrification in portions of the distribution system that receive GWTP water.

There is one analyzer installed for monitoring total chlorine at two separate locations. The sample line has to be switched on the analyzer from one location to the other, but the data recorded does not distinguish which sample line was used for the results.

**RECOMMENDATION #12:** Corona recommends detailed evaluation and improvements to the chlorine and ammonia injection and monitoring at the GWTP to ensure the optimum chlorine-to-ammonia ratio is achieved and properly monitored across all operational scenarios, as well as minimize nitrification potential in the GWTP treated water. One specific example would be to install monitoring of total chlorine, monochloramine, free ammonia, and pH at the GWTP entry point sufficiently downstream from the chemical injection points to obtain representative results after reaction time.

### Production

The GWTP was offline for the majority of the data review period. Production from the GWTP can be seen to supplement the SWTP production in Figure 19. Total median production for the SWTP and GWTP combined from 2018 to 2022 was 19.84 MGD. Groundwater production had a median of 5.30 MGD for the data available.



*Figure 19. Production at both Loeb GWTP and Pine Street SWTP.*

Production at the GWTP is monitored at individual wells, as well as at a totalizer located near Well 1. Table 4 shows that the totalizer at Well 1 inaccurately reports well flow totals. Manual calculation of the well totals show that the totalizer measurements are off by about 0.19 MGD every day.

**RECOMMENDATION #13:** Corona recommends updating or calibrating flow meters at all monitoring locations.

*Table 4. Inconsistencies in daily well flow totals.*

Well 1 (MGD)	Well 2 (MGD)	Well 3 (MGD)	Reported Well Flow Total (Well 1 totalizer)	Manual Well Flow Total (1+2+3)	Difference of Totals (Manual – Reported)
1.94	5.15	0.00	6.91	7.10	0.18
1.50	5.17	0.00	6.49	6.67	0.19
2.40	5.13	0.00	7.34	7.53	0.19
1.94	5.08	0.00	6.83	7.02	0.19
1.51	5.11	0.00	6.43	6.62	0.19

## Water Quality

Limited water quality data was available for groundwater due to sporadic use of the wells and inconsistent monitoring. Raw groundwater water quality from Well 1 and Well 2 is summarized in Table 5. The residual total chlorine, monochloramine and total ammonia are shown in Figure 20. Data was recorded and provided for 2021 as well, but was not received in time to be included in this report. Total chlorine and monochloramine have reasonable concentrations above 3 mg/L. The free ammonia concentration is an indicator of potential nitrification in the distribution system as it serves as nutrient for nitrifying bacteria. The median free ammonia concentration was 0.09 mg/L as N, with multiple individual readings above 0.1 mg/L. This is close to the recommended alert level for ammonia to prevent nitrification in the distribution system.

Table 5. Loeb GWTP raw water quality from Well 2.

Parameter	Minimum	25th Percentile	Median	75th Percentile	Maximum	Count
Aluminum	0	0.01	0.01	0.01	0.01	18
Calcium	3	3.2	3.4	3.6	3.7	17
Chloride	2.4	26	27	28	44	17
Color	4	5	5.5	7	9	16
Conductivity	418	455	458	464	522	17
Copper	0	0	0	0	0.03	17
Hardness (as CaCO <sub>3</sub> )	9	11	11	12	13	17
Magnesium	0.12	0.49	0.73	0.73	1.1	17
pH	8.39	8.4	8.5	8.6	8.8	17
Sulfate	0	0	0	0	0	17
Total Alkalinity (as CaCO <sub>3</sub> )	182	203	205	210	260	17
Total Iron	0	0	0	0	0.01	17
Total Manganese	0.01	0.01	0.01	0.01	0.02	17
Total Organic Carbon	0.34	0.36	0.37	0.39	0.63	17
Turbidity	0.05	0.08	0.11	0.15	0.71	17

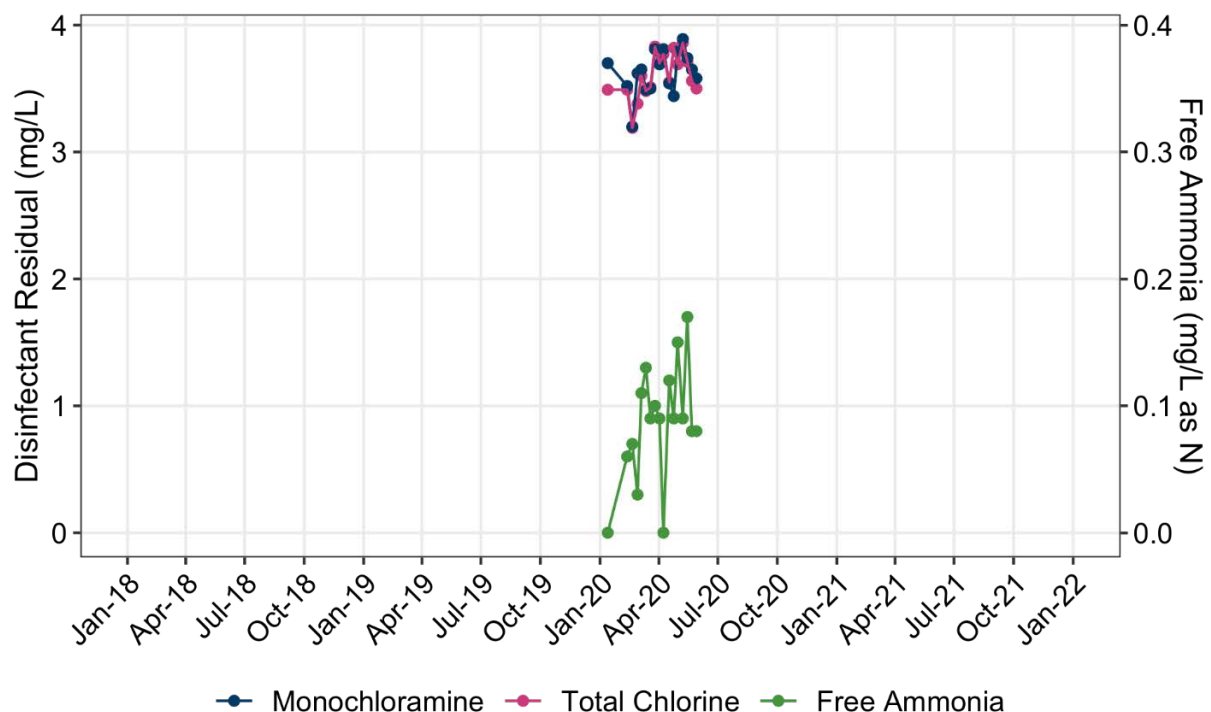


Figure 20. Residuals leaving Loeb GWTP.

The raw water pH from both Well 1 and Well 2 were above 8.5 SU, though only one data point was available for Well 1 (Figure 21). The treated water pH dropped to a median of 7.97 SU. As mentioned above, this pH will likely increase in the future due to the planned addition of caustic.

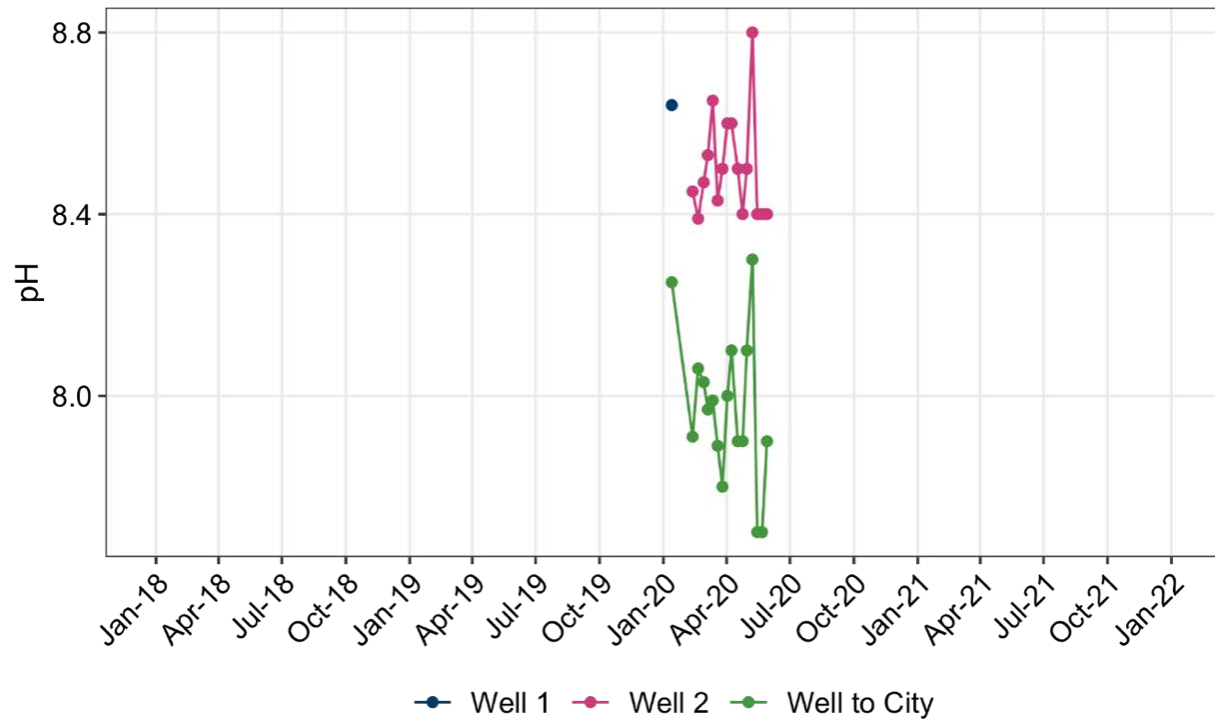


Figure 21. Groundwater pH for raw and treated water.

There was little total iron in the raw groundwater and treated groundwater. The median total iron in the treated groundwater was 0 mg/L. The maximum iron concentration measured was 0.02 mg/L, well below the SMCL of 0.3 mg/L (Figure 22).

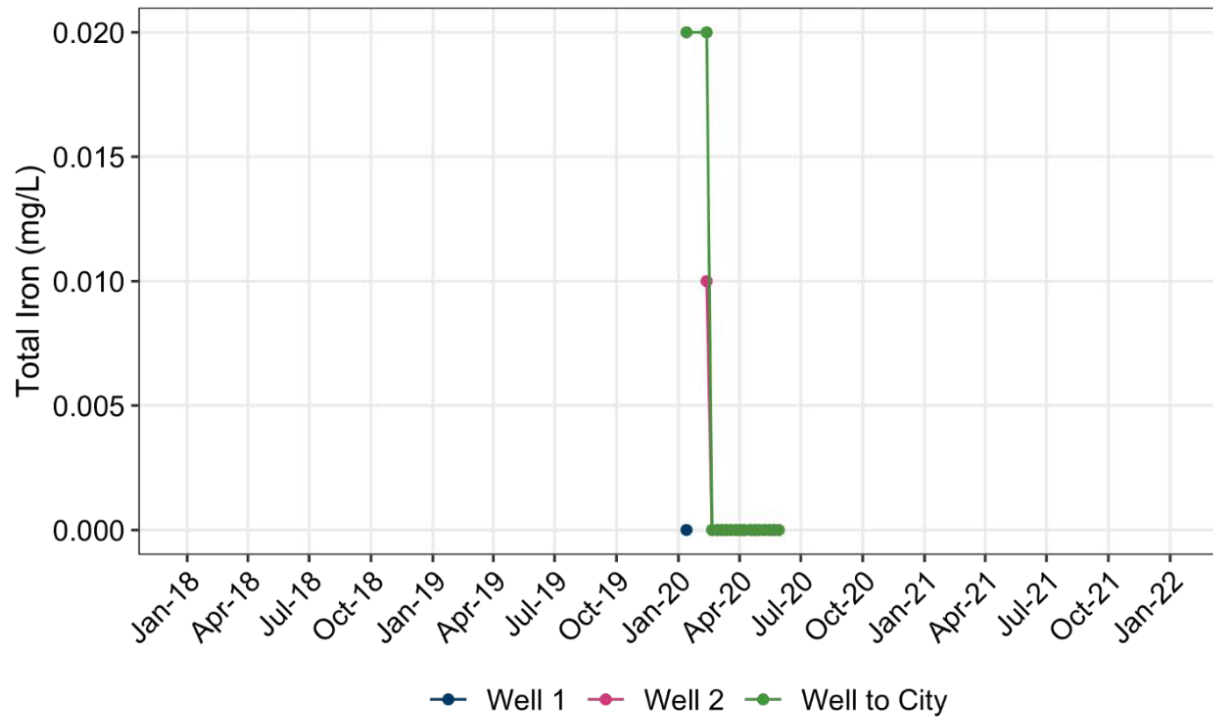


Figure 22. Total iron in raw and treated groundwater.

Total manganese ranged from 0.007 mg/L to 0.02 mg/L in the raw Well 2 water (Figure 23). While the highest manganese concentrations were below the SMCL of 0.05 mg/L, there were a few instances of higher manganese concentrations in the treated than the raw water. These data are limited and insufficient to adequately characterize water quality concerns that could be contributing to discolored water.

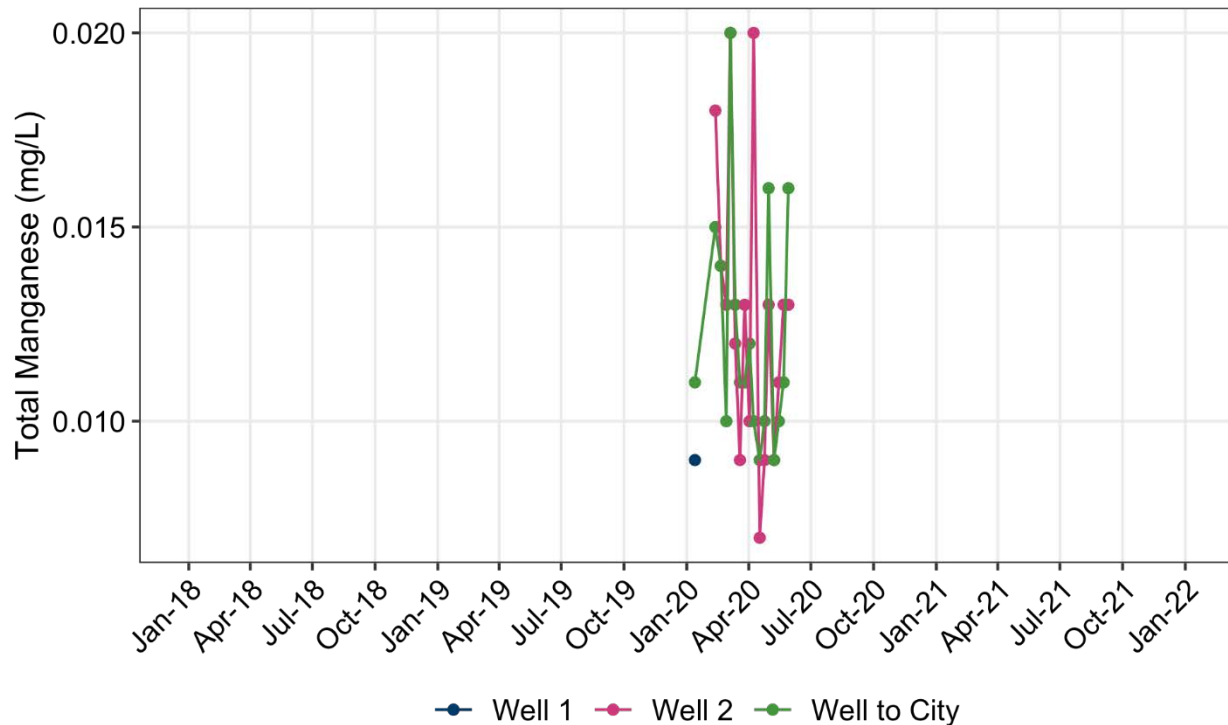


Figure 23. Total manganese in raw and treated groundwater.

**RECOMMENDATION #14:** Corona recommends weekly monitoring and recording of iron, manganese, pH and color in the raw and finished water when the wells are in operation. Other water quality parameters (such as those relating to corrosivity) should be monitored quarterly to verify stable water quality. Additional sampling and analysis may be warranted based on the results from this monitoring.

## Distribution System

### Storage Tanks

The City has 6 elevated storage tanks (Dishman, West, Northwest, Southwest, South, Prison Elevated Tank) and one ground storage tank (Prison Ground Tank) in the distribution system. A map of all tanks in relation to the GWTP and SWTP is shown in Figure 24.

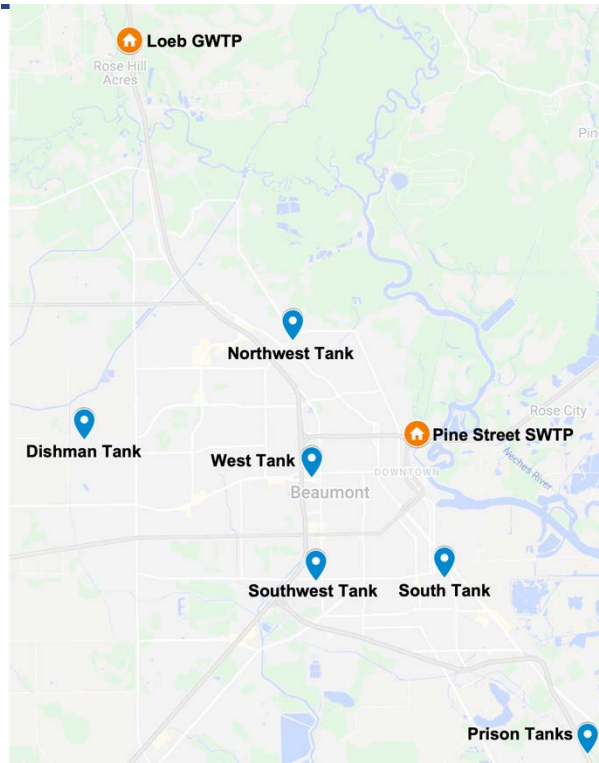


Figure 24. System overview map, including the SWTP, GWTP, and 7 storage tanks (2 at the prison site).

During the December 2021 onsite visit, Corona visited all of the tanks except for the West Tank and took residual readings using an SL1000 that are summarized in Table 6. Sampling was done to check for nitrification and disinfectant residual at the tanks.

Table 6. Storage capacity and disinfectant residuals at 6 City Storage tanks on 12/2/2021.

Storage Tank	Tank Capacity (MG)	Total Chlorine (mg/L)	Monochloramine (mg/L)	Free Ammonia (mg/L as N)	Nitrite (mg/L as N)
Northwest	1.5	3.82	3.85	0.15	na <sup>1</sup>
Dishman	2	0.35	0.21	0.34	0.094
Southwest	1	3.78	3.85	0.06	0.014
South	1	2.73	2.72	0.19	0.092
Prison (elevated)	0.3	1.14	1.04	0.14	0.073
Prison (ground)	2.6	3.37	3.54	0.06	0.00

<sup>1</sup>Chemkey leaked upon analysis and no result was reported

Nitrification is the microbiological process of converting free ammonia into nitrite and nitrate and leads to chemical, biological, and aesthetic water quality degradation that may impact regulatory compliance. The Dishman tank water quality indicated significant nitrification with a total chlorine residual falling below regulatory requirements while Corona was onsite. The tank was immediately taken offline and drained. Based on anecdotal evidence provided by City staff it appears that the Dishman tank may not turnover when the GWTP is in service due to higher water pressure.

In 2021, the City initiated a two-year inspection and cleaning frequency for all finished water storage tanks. Currently they are halfway through this process, with the remaining to be completed this year.

**RECOMMENDATION #15:** All finished water storage tanks should be inspected and cleaned for sludge or sediment accumulation, including manganese, every 3-5 years, or more frequently based on the rate of sediment accumulation. The City has cleaned half of the tanks in 2021 with the remaining half to be cleaned in 2022.

**RECOMMENDATION #16:** Corona recommends further investigation into the water stagnation and nitrification in the Dishman tank when the GWTP is in operation.

Nitrification also appeared to be underway at the prison elevated tank. The total chlorine residual was 1.14 mg/L with free ammonia and nitrite concentrations at 0.14 mg/L-N and 0.073 mg/L. However, this tank sources water from the Prison ground tank. Samples collected from the ground tank showed adequate chlorination and no signs of nitrification, indicating an issue specific to the elevated tower such as stratification or lack of turnover.

**RECOMMENDATION #17:** Corona recommends further investigating the nitrification issue at the Prison elevated tower to improve and maintain water quality.

### Nitrification Action Plan

The City provided their Nitrification Action Plan originally developed in 2017 and monitoring results from January to early March of 2022. The results from 2022 indicated significant nitrification occurring at multiple locations in the distribution system. The City indicated the following steps have been taken to control nitrification:

- Carefully monitor the free ammonia levels leaving the plants (daily or twice daily) to ensure they do not exceed 0.1 mg/L (but preferably less than 0.05 mg/L and greater than 0.01 mg/L)
- Installed a static mixer at the Loeb GWTP to improve (equally proportional) free chlorine residuals in the storage tanks
- Ran 4.25 total chlorine residual leaving the Loeb GWTP
- Check the free ammonia level at the entry point in distribution for the Loeb GWTP
- Installed a globe valve on the discharge line from the ammonia chemical pump at Loeb to attempt to control the fluctuation in the ammonia dosage flow
- Install caustic at the Loeb GWTP and raise the drinking water pH to 9 at both plants

- Initiated a review with Freese & Nichols of the ammonia dosing at Loeb, in order to improve dosing accuracy and optimize levels

Nitrification is the microbiological process of converting free ammonia into nitrite and nitrate and leads to chemical, biological, and aesthetic water quality degradation that may impact regulatory compliance. This phenomenon is especially common in chloraminated drinking water. As the chloramines break down, free ammonia is released and becomes food for the nitrifying bacteria. Conditions that indicate nitrification may begin soon (alert levels) or is already in progress (action levels) or are described in Table 7 (based on AWWA Manual M56, Nitrification Prevention and Control in Drinking Water).

*Table 7. Alert and Action levels for nitrification monitoring of free ammonia and nitrite.*

Parameter	Alert Level	Action Level
<b>Free Ammonia (mg/L as N)</b>	>0.1	>0.2
<b>Nitrite (mg/L as N)</b>	0.01	0.015

Managing nitrification is critical to prevention of discolored water events in the distribution system. Nitrification not only decreases the disinfectant levels, but also depletes water of dissolved oxygen (AWWA Manual M56). This lowers the oxidation-reduction potential (ORP) of the water. Under these conditions, stable iron and manganese in distribution system pipe scales are likely to dissolve and be released into the water resulting in discolored water events. Furthermore, nitrification lowers water pH which further increases iron and manganese solubility. As such, it is critical to optimize the City's Nitrification Action Plan to prevent nitrification, and consequently, discolored water events in future.

Upon review of the City's Nitrification Action Plan from 2017 shown in Figure 25 below, it appears the Action Level for free ammonia at average and high-water age locations are not consistent with industry best practices as shown in the table above.

Nitrification Action Plan Template Chloramine-Effectiveness Sample Suite						
Site	Chemical	Goal	Yellow Flag		Red Flag	
			Trigger	Actions	Trigger	Actions
Entry Point 001 (Surface Water)	Total / Mono	3.5	2.3	1. Verify results 2. Check and adjust dosage	1.8	1. Verify results 2. Check chemical feed metering pump. 3. Determine if looped in breakpoint chlorination. 4. Adjust dosage
	Free ammonia	<0.1	0.1		0.5	
Entry Point 002 (Groundwater)	Total / Mono	3.5	2.3	1. Verify results 2. Check and adjust dosage	1.8	1. Verify results 2. Check chemical feed metering pump. 3. Determine if looped in breakpoint chlorination. 4. Adjust dosage
	Free ammonia	<0.1	0.1		0.5	
Average Water Age	Total / Mono	2.9	1.0	1. Verify results 2. Test mono-chloramine, free ammonia, and pH 3. Test nearby water mains to determine if isolated or systemic event.	0.7	
	Free ammonia	0.1	0.2		0.5	
High Water Age	Total / Mono	2.3	0.8	4. If mono and free ammonia acceptable, flush until residual improves.	0.6	1. Verify results 2. Flush to raise residual 3. Check mono-chloramine and free ammonia levels at source and nearby water mains to determine if systemic or localized. 4. Free chlorine burn if systemic
	Free ammonia	0.2	0.27		0.5	

Figure 25 City of Beaumont's Nitrification Action Plan Alert and Action Levels for Chloramines

In addition, the alert and action levels for nitrite shown in Figure 26 below are not consistent with industry best practices.

**RECOMMENDATION #18:** Corona recommends the City's Nitrification Action Plan be reviewed and revised for consistency with industry best practices such as AWWA Manual M56, Nitrification Prevention and Control in Drinking Water.

Nitrite/Nitrate						
Site	Chemical	Baseline	Yellow Flag		Red Flag	
			Trigger	Actions	Trigger	Actions
Source Water (Surface Water)	Nitrite	0.15	0.18	1. Verify results 2. Determine if source changes 3. Re-evaluate and adjust baseline and NAP if necessary 4. Clean clearwell	0.5	1. Verify results 2. Re-test source water; re-evaluate baseline
	Nitrate	0.15	0.18	1. Verify results 2. Determine if source changes 3. Re-evaluate and adjust baseline and NAP if necessary 4. Clean clearwell	0.5	
Source Water (Groundwater)	Nitrite	0	0.1	1. Verify results 2. Determine if source changes 3. Re-evaluate and adjust baseline and NAP if necessary 4. Clean clearwell	0.5	1. Verify results 2. Re-test source water; re-evaluate baseline
	Nitrate	0	0.1	1. Verify results 2. Determine if source changes 3. Re-evaluate and adjust baseline and NAP if necessary 4. Clean clearwell	0.5	
Average Water Age	Nitrite	0.15	0.2	1. Verify results 2. Check additional mains 3. Determine if localized 4. Flush 5. Re-test for nitrite	0.5	1. Verify results 2. Test additional mains 3. Check pH; free ammonia, test for nitrification bacteria 4. Determine if localized or systemic: if localized, flush; if systemic, free chlorine burn
	Nitrate	0.15	0.2	1. Verify results 2. Check additional mains 3. Determine if localized 4. Flush 5. Re-test for nitrite	0.5	1. Verify results 2. Test additional mains 3. Check pH; free ammonia, test for nitrification bacteria 4. Determine if localized or systemic: if localized, flush; if systemic, free chlorine burn
High Water Age	Nitrite	0.15	0.4	1. Verify results 2. Check additional mains 3. Determine if localized 4. Flush 5. Re-test for nitrite	0.7	1. Verify results 2. Test additional mains 3. Check pH; free ammonia, test for nitrification bacteria 4. Determine if localized or systemic: if localized, flush; if systemic, free chlorine burn
	Nitrate	0.15	0.4	1. Verify results 2. Check additional mains 3. Determine if localized 4. Flush 5. Re-test for nitrite	0.7	1. Verify results 2. Test additional mains 3. Check pH; free ammonia, test for nitrification bacteria 4. Determine if localized or systemic: if localized, flush; if systemic, free chlorine burn

Figure 26. City of Beaumont's Nitrification Action Plan Alert and Action Levels for Nitrite and Nitrate

## Customer Complaints

In the summer of 2021, the City had an influx of discolored water complaints. As shown in Figure 27, complaints spiked to 737 for the month of June 2021. This was 1.8 times the previous maximum in July 2020 and 6 times the median monthly complaints for the time period shown. Data provided was from June 2020 to September 2021. The peak in July 2020 occurred during a 12-inch main break, and the June 2021 peak occurred during fire hydrant testing and a free chlorine conversion.

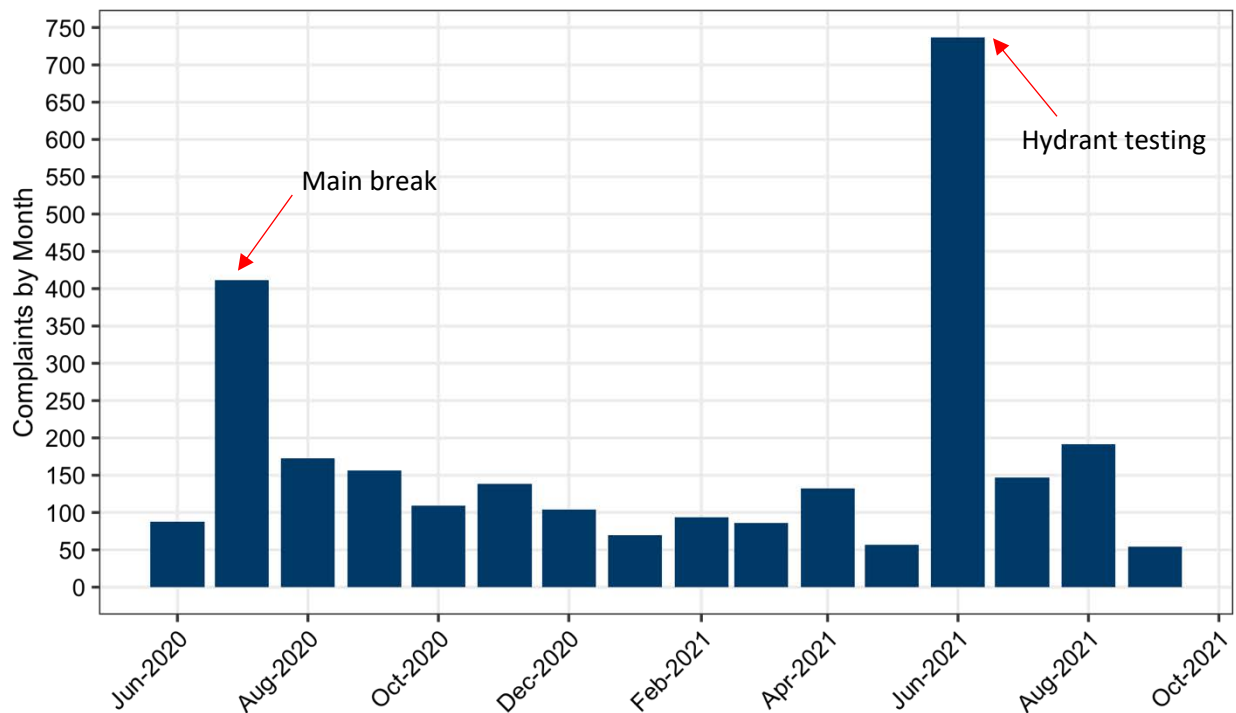
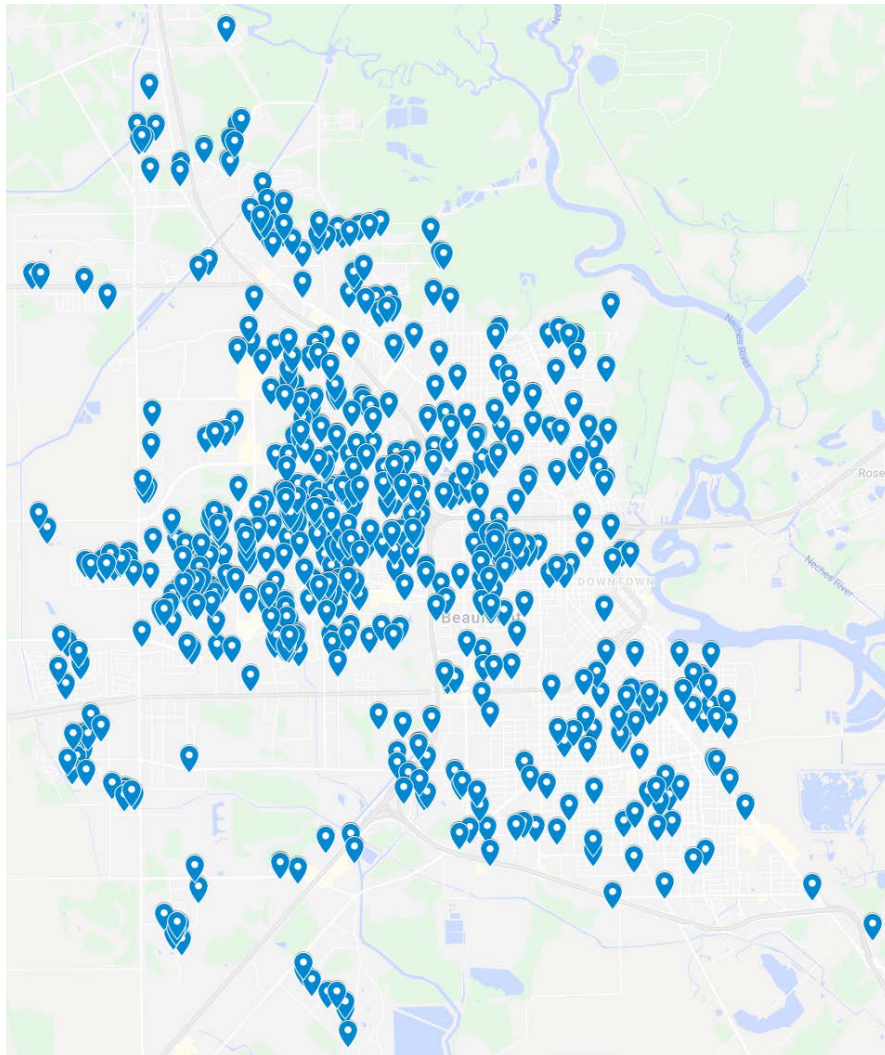


Figure 27. Historical discolored water complaints by month.

These complaints were not localized to a specific area in the distribution system, but randomly across the city, as shown in the June 2021 report of discolored water complaints (Figure 28).



*Figure 28. Discolored water complaint locations from June 1, 2021 to June 30, 2021.*

### Flushing

The City is conducting weekly flushing at 19 fire hydrants for 15 minutes each. In addition to weekly flushing, monthly flushing is done at 30 fire hydrants for 15 minutes each. The technician takes a route that circles the city. Also done monthly is dead-end flushing, as required by TCEQ. Flushing on this schedule reduces customer complaints to a minimum. Lastly, the City performs spot flushing as-needed based on complaints.

The City does not have a detailed plan showing how to flush the system from entry point to furthest point in a unidirectional manner. A unidirectional flushing plan can be used not only for addressing water quality concerns and complaints but also when changes are implemented that necessitate quick turnover of the distribution system such as emergency response.

**Recommendation 19:** The City should develop a unidirectional flushing plan for the distribution system.

## Recommendations

The recommendations for the City of Beaumont water system are presented in two tables based on their impact on discolored water. The recommendations shown in Table 8 will have the greatest effect on reducing discolored water from iron and manganese in the distribution system. Recommendations are numbered by their appearance in the report but ordered in the table with the highest impact at the top.

The high impacted recommendations for chlorine dioxide (No. 11) and filter-to-waste (No. 6) require significant capital investment. The City requested feasibility level cost information for these recommendations; Corona developed an AACE (Association for the Advancement of Cost Engineering) Class 5 estimate with an expected accuracy range of -50/+100%. The estimated capital cost for the chlorine dioxide system is \$1,300,000 inclusive of design, permitting, equipment, and installation cost. The estimated capital cost to implement filter-to-waste is \$4,000,000 inclusive of design, materials including valves, fittings, and piping, as well as a sump and pump and installation cost.

*Table 8. List of recommendations with the highest impact on addressing discolored water.*

No.	Location	Recommendation
11	Pine SWTP	Implement chlorine dioxide (ClO <sub>2</sub> ) be used in the raw water ahead of alum as a pre-oxidant. This will convert dissolved iron and manganese to particulates which can be removed in the plant processes.
8	Pine SWTP	Establish consistent manganese monitoring and recording throughout the SWTP as discolored water is a recurring problem for the City, as well as weekly manganese monitoring at the high service pumps tested by an external laboratory for confirmation.
14	Loeb GWTP	Establish weekly monitoring and recording of iron, manganese, pH, and color when the wells are in operation. More data is needed to understand the iron and manganese levels in these wells and the extent to which they may contribute to discolored water when in service. Other water quality parameters (such as those relating to corrosivity) should be monitored quarterly to verify stable water quality. Storage tanks should also be occasionally inspected for sludge or sediment accumulation, including manganese.
9	Pine SWTP	Perform daily review of manganese levels through each process unit of the SWTP to ensure there is no trend of increasing manganese levels through any process unit.
10	Pine SWTP	Evaluate the filter backwash frequency and duration to maximize removal of manganese from the filters.

15	Distribution System	All finished water storage tanks should be inspected and cleaned for sludge or sediment accumulation, including manganese, every 3-5 years, or more frequently based on the rate of sediment accumulation.
19	Distribution System	The City should develop a unidirectional flushing plan for the distribution system.

Table 9 will also contribute to the reduction and prevention of discolored water from iron and manganese in the distribution system. However, these recommendations are not as directly impactful and may take much longer to implement. The recommendations are also ranked as 1-3 based on their priority. Priority 1 recommendations are the highest, most immediate priority and should be implemented within 1-3 months. Priority 2 recommendations should be implemented within 6-12 months and Priority 3 recommendations should be implemented within 12-18 months.

*Table 9. List of recommendations to support discolored water prevention and optimization of other water quality processes.*

No.	Location	Recommendation	Priority
1	Pine SWTP	Install online pH analyzers to monitor pH in real time to facilitate an improved monitoring and response strategy for changes in raw water pH.	3
2	Pine SWTP	Repair or replacement of the sludge drains to restore the units back to normal operations for regular maintenance of the basins.	2
3	Pine SWTP	Begin monitoring recording settled water parameters to ensure water quality, individual clarifier performance, and address any concerns with TCEQ.	1
4	Pine SWTP	Equalize the flow across all filters to prevent disproportionate wear and tear on filters processing more water.	1
5	Pine SWTP	Establish a turbidity goal of <2.0 NTU in settled water and <0.1 NTU in the filter effluent to treat the water more conservatively, and as recommended by AWWA's Partnership for Safe Water Program.	1
6	Pine SWTP	Install filter-to-waste capability at the SWTP to better facilitate improved finished water turbidities to meet optimization goals, and reduce manganese release from filter media upon return to service.	3
7	Pine SWTP	Ensure recycle flow data is continuously monitored and recorded and historical data is available for review and analysis.	1
12	Loeb GWTP	Conduct a detailed evaluation and improvements to the chlorine and ammonia injection and monitoring at the GWTP to ensure the optimum chlorine-to-ammonia ratio is achieved and properly	1

No.	Location	Recommendation	Priority
		monitored across all operational scenarios, as well as minimize nitrification potential in the GWTP treated water.	
13	Loeb GWTP	Update and calibrate flow meters at all monitoring locations.	1
16	Distribution System	Investigate the water stagnation and nitrification in the Dishman tank when the GWTP is in operation and test or implement potential solutions.	1
17	Distribution System	Investigate the nitrification issue at the Prison elevated tower and test or implement potential solutions to maintain water quality.	1
18	Distribution System	Review and revise the City's Nitrification Action Plan for consistency with industry best practices such as AWWA Manual M56, Nitrification Prevention and Control in Drinking Water.	2